DEVELOPMENT AND VALIDATION OF THE UNVENTED TROMBE WALL MODEL IN ENERGYPLUS

BY

PETER GRAHAM ELLIS

B.A., Carleton College, 1995

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Mechanical Engineering
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2003

Urbana, Illinois

ACKNOWLEDGEMENTS

The author expresses his sincere appreciation to his advisors, Dr. C. O. Pedersen and Dr. R. J. Liesen, for their guidance and assistance with this project, and for having faith in the potential of a physics major from a small liberal arts college. A special thanks goes to Dr. J. D. Balcomb for graciously providing the raw data from the Los Alamos experiment and for lending his expertise and advice at various stages of the project. Also thanks to Darrell Holt at the Los Alamos National Laboratory for supplying the indispensable weather data. Finally, the author thanks his family and friends for their constant support and encouragement. This thesis could not have been completed without them.

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List of Symbols

a	aspect ratio, H/L
A	area (m^2)
ACH	air changes per hour
BLC	building load coefficient (W/K)
c_p	specific heat (J kg/K)
F_{ij}	view factor from i to j
g	acceleration of gravity (m/s^2)
Gr	Grashof number
Gr_L	Grashof number based on air gap spacing L
h_c	interior convection coefficient (W/m^2 K)
$h_{c,net}$	net interior convection coefficient (W/m^2 K)
H	height (m)
k	thermal conductivity (W/m K)
L	length of air gap spacing or thickness of wall (m)
m	mass (kg)
Nu	Nusselt number
Nu_L	Nusselt number based on air gap spacing L
Pr	Prandtl number
q''	heat flux (W/m^2)
Ra	Rayleigh number
Ra_L	Rayleigh number based on air gap spacing L
R	thermal resistance (m^2 K/W)

R_{net}	net thermal resistance (m^2 K/W)
t	time (s)
T	temperature (K)
T_0	initial temperature (K)
T_1	hot wall temperature (K)
T_2	cold wall temperature (K)
T_∞	temperature after a very long time (K)
UA	thermal conductance (W/K)
V	volume (m^3)
$\dot{V}$	volumetric flow rate (m^3/s)
α	thermal diffusivity (m^2/s)
α_{solar}	solar absorptivity
α_{vis}	visible absorptivity
β	volumetric thermal expansion coefficient (1/K)
ε_{therm}	thermal emissivity
ν	kinematic viscosity (m^2/s)
θ	tilt angle (radians)
ρ	density (kg/m^3)
τ	time constant (1/s)
τ_{solar}	solar transmissivity

1 INTRODUCTION

1.1 GREEN BUILDINGS

Although the concept is not new, green buildings have enjoyed an increase in popularity in recent years. Green buildings are designed to be more environmentally friendly than standard buildings. Many green buildings achieve this be being more energy efficient.

In the United States buildings consume 65% of the nation's electricity and 36% of the nation's total energy (U. S. Department of Energy 2001). Improvements in energy efficiency for this broad sector have the potential for a tremendous overall reduction in energy consumption. Less consumption means fewer power plants are required and fewer pollutants and greenhouse gases are released to the atmosphere.

Passive solar design can greatly increase the energy efficiency of a building. Passive solar design embodies a variety of strategies and technologies that use the free energy received from the sun for the purpose of heating and lighting building spaces. One passive solar technology for green buildings is the Trombe wall.

1.2 TROMBE WALLS

1.2.1 Principles

The Trombe wall is a clever device for collecting and storing heat from the sun during the day and releasing heat into a building space during the night; they are a means for free solar space heating. The wall is typically located on the south face of a building (in the northern hemisphere) to maximize its solar exposure throughout the year. Overhangs are used to shade the wall during the summer to prevent overheating but allow sunlight at lower angles to heat the wall during the winter. Heat is collected and stored in the thick concrete wall. One or more layers of glazing on the exterior and an optional selective surface turn the wall into a one-way heat valve. The glazing forms an air gap between the wall surface and the outside air that helps to insulate the wall from outside convection. The selective surface is adhered to the wall surface and is characterized by a very high absorptivity and very low emissivity, allowing solar radiation to be absorbed but preventing it from being re-emitted as longwave radiation.

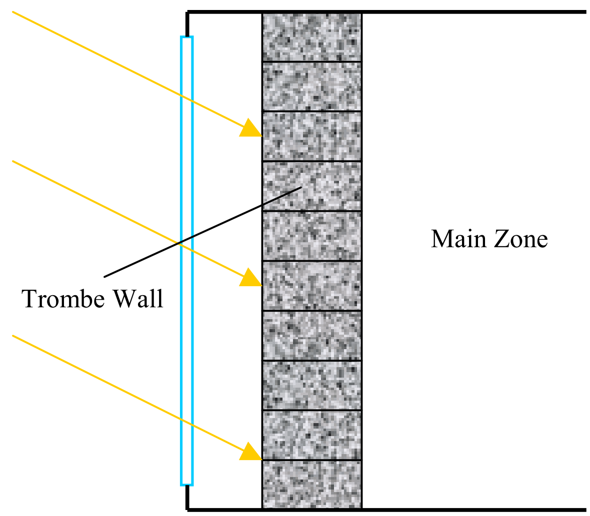

Figure 1. Diagram of Trombe wall.

At night the heat stored in the wall finally propagates through the concrete to reach the building space. This passive solar strategy is called indirect gain. Because much of the heat from the wall is delivered radiantly, occupants report a more favorable thermal comfort compared to convective forms of heating.

Vents are sometimes placed at the bottom and top of the wall to allow some of the zone air to circulate through the Trombe air gap. The stack effect pulls colder air in at the bottom vent and pushes warmer air (heated by the wall) out at the top. Because natural convection drives the air flow this is considered a passive Trombe wall system. The addition of an electric fan forces the air flow and converts the system into an active Trombe wall system. Either type of ventilation helps bring heat into the building space earlier than by conduction alone.

1.2.2 History

The principle of thermal storage has long been applied in the native American adobe dwellings of the American southwest and other similar habitations found across the early world. Much like the Trombe wall, the thick adobe walls absorb and store heat during the day to provide natural heating into the night.

An American named E. L. Morse was the first to describe the Trombe wall concept in a 1881 patent (Morse 1881). Ahead of its time, it was not until 1972 that the idea was repatented and popularized by the French inventor Felix Trombe and the architect Jacques Michel (Trombe 1972). The Trombe wall is also known as a Trombe-Michel wall, solar wall, thermal storage wall, collector storage wall, or simply storage wall.

Although texts books typically describe the Trombe wall with vents (Trombe's original wall was ventilated) (Trombe 1977), research has shown that in most cases, the unvented Trombe wall performs better than the vented Trombe wall (Balcomb et al. 1980a). Ventilation tends to negate the storage effect of the wall and eliminates the effectiveness of the air gap as insulation (Balcomb 2003). The preferred design is now a sealed air gap between the glazing and the wall, making it an unvented Trombe wall. Only unvented Trombe walls are considered in this thesis.

Today Trombe walls are a sophisticated but simple solution for providing passive solar heating to buildings. They have been shown to be an effective technology for reducing heating energy, as much as 47% in residential cases (Balcomb 1992). Some of the most publicized Trombe walls in recent years have been designed by the National Renewable Energy Laboratory (NREL) in Golden, Colorado. At their facility there are two buildings with Trombe walls—the Solar Energy Research Facility and the NREL Visitor Center. A third building is the Zion Visitor Center at Zion National Park, Utah. Some well-known residential buildings with Trombe walls include the Grand Canyon House in Arizona and the Van Geet residence in Colorado (NREL 2003). A number of buildings with Trombe walls were built and monitored in the late 70s and early 80s (Frey 1992). The author is not aware if these buildings are still in operation today.

1.3 COMPUTER SIMULATION

Much passive solar design is done without any analysis. It is done by intuition, imitation, or rules-of-thumb (Balcomb 1992). Advances in desktop computer processing power allow extremely complex whole-building energy analyses to be performed much more rapidly and inexpensively than when the passive solar movement began in the 70s.

Computer simulation programs can play an important role as an evaluation tool for passive solar designs for green buildings. They can allow a researcher or designer to vary physical parameters and optimize designs. The EnergyPlus program is one recent building energy simulation tool capable of such an analysis.

This thesis describes the development and validation of the Trombe wall model for the EnergyPlus program. To validate the model, Trombe wall heat transfer correlations are compared to well-established correlations in the literature, and to other computer simulation programs. Since a Trombe wall is an integral part of a building structure, it cannot be reliably tested in isolation. For this reason an experimental validation of the model was completed using existing data from test cell experiments conducted at the Los Alamos National Laboratory in 1981-82 (McFarland et al. 1982). To calibrate various physical parameters, a reference cell and a direct gain cell are also simulated.

1.4 SUMMARY

The Trombe wall is a passive solar technology that has been around for several decades and has been proven to perform effectively. If the next generation of building energy simulation programs are to play a role in the evaluation of passive solar designs for green buildings, it is necessary that these programs are capable of accurately simulating Trombe walls.

2 LITERATURE REVIEW

The Trombe wall has been the subject of numerous experiments and papers. The majority of the work is from the late 70s and early 80s when interest in passive solar technologies was at its zenith.

The literature can be divided into five categories:

1. Case studies
2. Test cells
3. Design guides
4. Basic science
5. Computer simulation

Not every category is equally useful for the purpose of validating a Trombe wall model. All are mentioned here for completeness and merit at least a short description below.

2.1 CASE STUDIES

Case studies analyze real buildings that are occupied by people for everyday residential or commercial use. Measurements are generally made in terms of energy performance on the time scale of a day or month. Private homes seem to be a favorite for passive solar case studies. Homes containing a Trombe wall, such as the Balcomb home, have been analyzed extensively (Balcomb et al. 1979, 1980b, 1981). The original Odeillo houses in France (which made the Trombe name famous) were case studies (Trombe 1977).

Case studies are very useful for determining the efficacy of a technology under realistic conditions and usage. The validation of a computer simulation model, however, requires highly controlled conditions with performance measurements at a time scale comparable to the simulation time step. Case studies are not so useful for validation and will not be discussed further.

2.2 TEST CELLS

Test cells are small one or two room buildings that are constructed specifically for experimental testing. They offer highly controlled conditions and are equipped with instrumentation for measurements on the time scale of an hour or less. Test cells are ideal for computer model validation.

Test cell experiments are designed to meet different objectives. Some are intended for proof-of-concept, i.e. to determine if a given passive solar device works at all. Other experiments directly compare two or more devices under identical conditions to see which works best. Others still are designed for generating data that can be used for computer model validation.

A number of test cell experiments have included Trombe walls. By far, the most prolific set of test cells for Trombe wall research was located at the Los Alamos National Laboratory (LANL) in New Mexico. The Los Alamos data has been influential in several derivative studies. Although a number of other test cell experiments are known to have been performed at various locations (Moore 1982, 1992), apparently little of that research made it to publication. The Los Alamos experiments and other test cell research is surveyed below.

2.2.1 Los Alamos

The Los Alamos test cell experiments were performed from 1977 to 1982 (Balcomb et al. 1978, SERI/TR-0924-2 1980, McFarland 1982, McFarland et al. 1982). Some preliminary work was also possibly done as early as 1976. By 1977 fourteen test cells were in operation.

Consisting of seven small buildings, each divided into two test cells, the 1981-82 experiment was intended to compare a variety of passive solar heating technologies, such as sun spaces, direct gain spaces, phase change materials, water walls, and several varieties of Trombe wall. "This testing was done primarily to determine the relative efficiency of various passive solar heating concepts and to obtain data that could be used to validate computer simulation programs." (McFarland et al. 1982). By the 1981-82 heating season, the test cells were as shown in Figures 2 and 3.

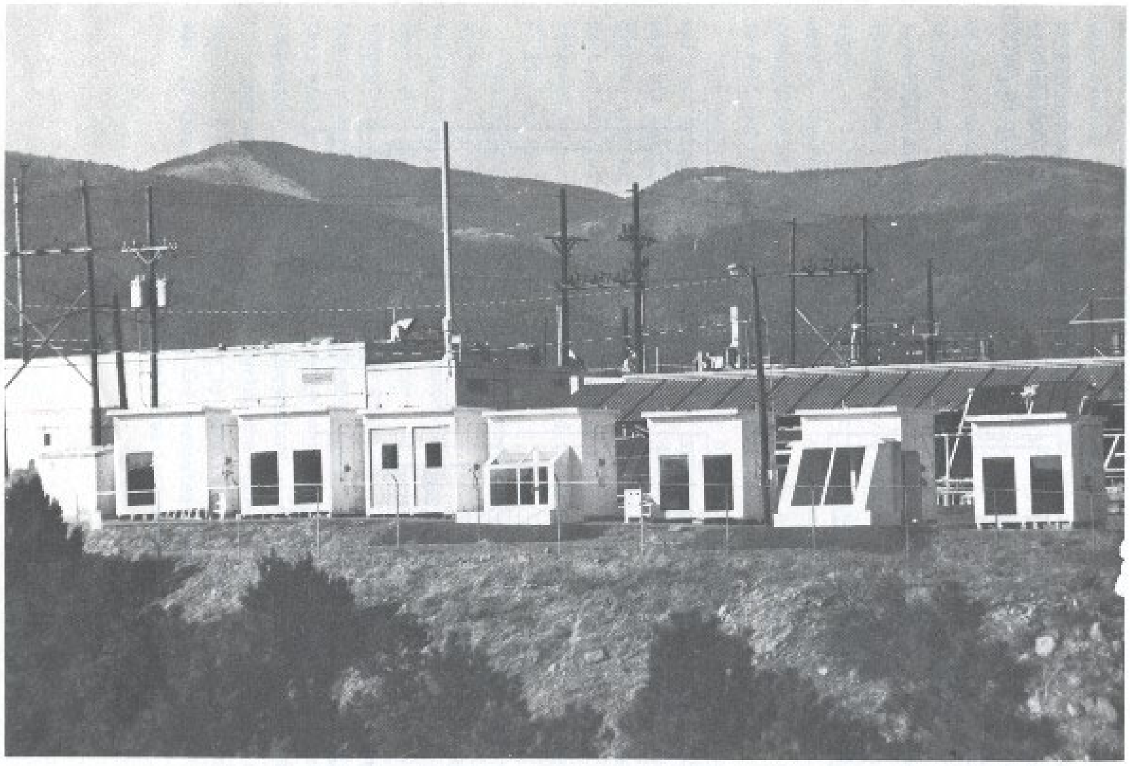

Figure 2. Test cells at Los Alamos (McFarland 1982).

A different passive solar device is installed on the south face of each cell. The remainder of the cell is insulated and designed to have minimal thermal mass. From year to year, the general test cell construction remained relatively unchanged. By 1980, however, forced ventilation and auxiliary heating were added to the test cell set-up. Forced ventilation was accomplished with a small fan to slightly pressurize the cells so that infiltration could be minimized as an unknown. Auxiliary heating controlled at a set-point temperature was used to maintain each cell above a minimum realistic air temperature. This gave a more realistic operating profile and made it possible to directly compare energy savings and to extrapolate the results to real buildings (Balcomb 1992).

Over the years, the number of variables measured and the sophistication of the data acquisition system increased. By 1980 the cells were heavily instrumented with measurements automatically recorded by a state-of-the-art data acquisition system.

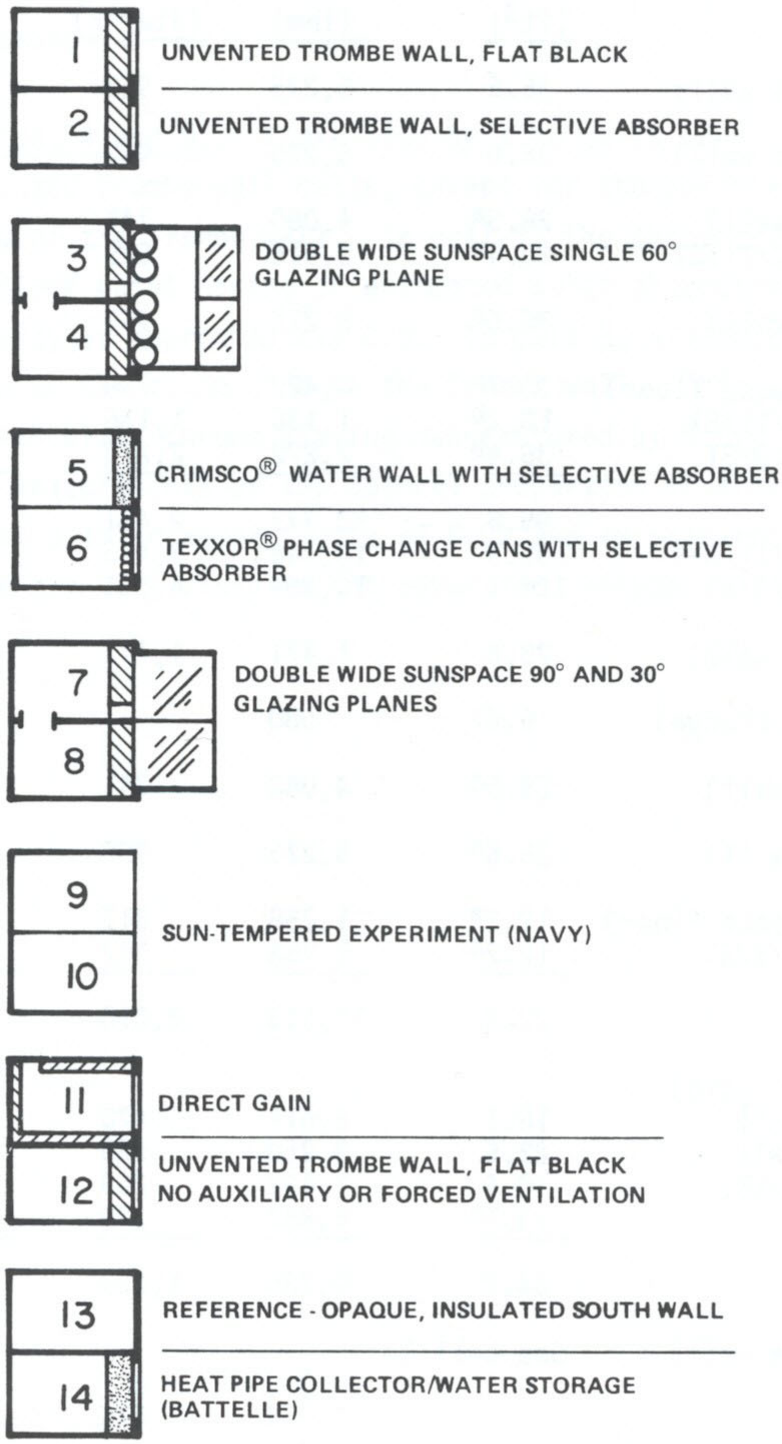

Figure 3. Test cell assignments at Los Alamos (McFarland et al. 1982).

Some of the measured variables included:

- Globe temperature
- Select surface temperatures
- Auxiliary heat

Detailed weather measurements were also recorded at a weather station on site.

The 1981-82 heating season was the last published test cell experiment out of Los Alamos. More information about the Los Alamos test cells and experiment appears below as part of the experimental validation section.

2.2.2 Los Alamos Derivative Research

Data from the Los Alamos test cells have been used in several important derivative studies. An early set of data was used by Goldstein (1978) to verify an entirely analytical description of thermal response for the Trombe wall cell and direct gain cell. By approximating the weather conditions as a series of sinusoidal functions, he was able to obtain reasonable agreement with the data. In the process, important material properties of the test cell concrete were deduced and found to be significantly different from the nominal values in the Los Alamos reports.

The same year of data for the direct gain cell was also used in a validation of the BLAST program (Andersson et al. 1980, Bauman et al. 1983). Because the test cells were not yet equipped with forced ventilation, the infiltration rate was an unknown variable. It was ultimately difficult to match the results without some arbitrary calibration of an infiltration parameter.

2.2.3 Beyond Los Alamos

The success of the Los Alamos test cell experiments inspired imitation. Two independent sets of test cell experiments based on the Los Alamos design were conducted: one at the National Center for Appropriate Technology in Butte, Montana (Palmiter et al. 1978), the other at the University of Pennsylvania (Duncan and Prowler 1978). Both experiments included a Trombe wall. There do not seem to be any further publications about these test cells.

Another test cell experiment was uniquely designed to examine convective heat transfer inside the channel of a *vented* Trombe wall (Casperson and Hocevar 1979). Detailed measurements were used to map the velocity and temperature profiles at different heights and flow conditions for an air gap of 2, 4, and 6 inches. Although not relevant for the present validation of unvented Trombe walls, this research is clearly useful for a future validation of vented Trombe walls.

Outside of the United States, an extensive passive solar program called PASSYS managed test cells across eleven European countries from 1986-1993. The test cells were designed to measure the thermal performance of standard building components and passive solar components. An "internally vented" Trombe wall was constructed in Lyngby, Denmark (PASSYS 1994), however, no published results have been found. A Trombe wall test cell, however, does appear to have been used in a validation of the ESP-r program (Strachan 2000).

2.3 DESIGN GUIDES

Simplified calculations or rules-of-thumb for constructing Trombe walls are frequently presented as design guides. Many papers have been written on this topic. The most comprehensive design guides were a direct product of the Los Alamos test cell research. The three volume *Passive Solar Design Handbook* (Anderson et al. 1980; Balcomb et al. 1980b; Jones et al. 1982) represents the cumulative knowledge of more than five years of test cell experiments and case studies performed by the Los Alamos researchers. The information in the *Handbook* volumes was later distilled, re-compiled, edited, and published by ASHRAE as *Passive Solar Heating Analysis: A Design Manual* (Balcomb et al. 1984).

Although design guides are not necessarily useful for validation purposes, they are occasionally able to fill in a missing piece of information not available from other sources.

2.4 *BASIC SCIENCE*

Basic science refers to the study of the fundamental heat transfer phenomena that affect Trombe wall efficiency. Many of these important phenomena are not unique to the Trombe wall, for example, conduction through a wall, solar transmitted through glazing, heat loss through glazing, longwave radiation exchange, etc. The EnergyPlus models that govern these phenomena have already been validated for standard building components such as walls and windows. The only phenomenon that is perhaps unique to Trombe walls is the convection occurring in the air gap between the glazing and the Trombe wall surface.

2.4.1 Natural Convection

Convection within the unvented Trombe wall air gap is usually described as natural convection in a channel of high aspect ratio. Because a number of applications exist for which such conditions apply, there are many references that treat the problem generally (MacGregor and Emery 1969, Randall et al. 1979). One familiar application is the convection in the air gap between two layers of glazing in a multipane window (Wright 1989, 1996, ISO 15099 2000). There are also several studies specific to Trombe walls (James and Gross 1991, Warrington and Ameel 1995).

2.5 *COMPUTER SIMULATION*

Trombe walls have been simulated on computers since their revival in the 70s. Early models used a thermal network with several nodes to simulate a Trombe wall (Balcomb et al. 1977). PASOLE was a well-known passive solar simulation program of the time which was validated using Los Alamos test cell data (McFarland 1978).

A number of contemporary building thermal simulation programs are capable of modeling Trombe walls, including BLAST, DOE-2, TRNSYS, SUNREL, and ESP-r. A brief survey of the Trombe wall models used by these programs is given below. Other models serve as a comparison to the EnergyPlus model. The correlations for convection coefficients in the air gap are revisited and compared to EnergyPlus in a later section.

2.5.1 BLAST

The Building Loads Analysis and System Thermodynamics (BLAST) program includes a Trombe wall object (Walton 1981). Convection coefficients in the air gap of the unvented Trombe wall are derived from an empirical correlation by Mull and Reiher (1930). The BLAST model has not been validated against experimental data.

2.5.2 DOE-2

The DOE-2 program includes a Trombe wall object. DOE-2 uses the same correlation for unvented convection as BLAST (Mull and Reiher 1930). The model was validated using Los Alamos test cell data (Moore et al. 1981).

2.5.3 TRNSYS

The Transient Systems Simulation (TRNSYS) program includes a Trombe wall object referenced as "Type 36: Thermal Storage Wall". Only one Trombe wall is allowed per simulation (TRNSYS Main Manual). Convection coefficients in the air gap of the unvented Trombe wall come from Randall et al. (1979). It is not known if the TRNSYS model has been experimentally validated.

2.5.4 SUNREL

The SUNREL program, formerly SERIRES, is intended for the thermal analysis of small residential buildings. Trombe walls are modeled by the program, but the user must input the combined convective and radiative heat transfer coefficient for the air gap (SUNREL 2000). In some cases, accuracy of the results may be limited by the isotropic sky model that is assumed.

2.5.5 ESP-r

Documentation for ESP-r (2001) suggests that Trombe walls can be simulated with the program. However, not enough information is given to determine if a separate Trombe wall model exists per se. Since convection coefficients can be externally defined by the user, it is likely that the Trombe wall is modeled as a special zone where the user provides the desired correlation. Some validation of passive solar components in ESP-r, including a Trombe wall, appears to have been completed using the PASSYS test cells (Strachan 2000).

2.6 SUMMARY

The test cell literature, especially from Los Alamos, was drawn upon heavily for the present validation. The convection correlation literature and comparison to correlations used by existing computer simulation models was also used to help validate the model.

3 EnergyPlus Trombe Wall Model Development

3.1 Heat Balance Method

The Trombe wall model is based on the heat balance method as implemented in EnergyPlus. The method makes the following assumptions:

1. Zone air is well-mixed
2. Air entering the zone mixes immediately with the zone air
3. Uniform surface temperatures
4. Diffuse radiating surfaces
5. One dimensional heat transfer

3.2 Trombe Wall Model

The Trombe wall is modeled using standard EnergyPlus objects. A special Trombe zone is defined in the air gap between the Trombe wall and the glazing. The wall and glazing are standard EnergyPlus surfaces. The wall is connected to the main zone as an interior partition. The glazing is essentially a very large window that covers much of the exterior wall of the zone. If a selective surface is used, it is simply defined as a material with the relevant thermal properties in the construction definition of the wall.

This approach was chosen to take advantage of the existing heat transfer capabilities in EnergyPlus and to allow flexibility for modeling unique wall designs, such as embedded windows, glazing variations, non-vertical walls, etc.

The critical difference between a Trombe zone and a normal zone is in its unique geometry. The Trombe zone has a much greater aspect ratio of height to width. A normal zone typically has an aspect ratio on the order of 1 or less. The aspect ratio of a Trombe zone, defined as the ratio of the vertical wall height to the air gap width, can be on the order of 10 to 100. The effect of such a high aspect ratio is to change the fundamental convective heat transfer phenomena in the zone. For this reason a special convection algorithm must be used for the Trombe zone.

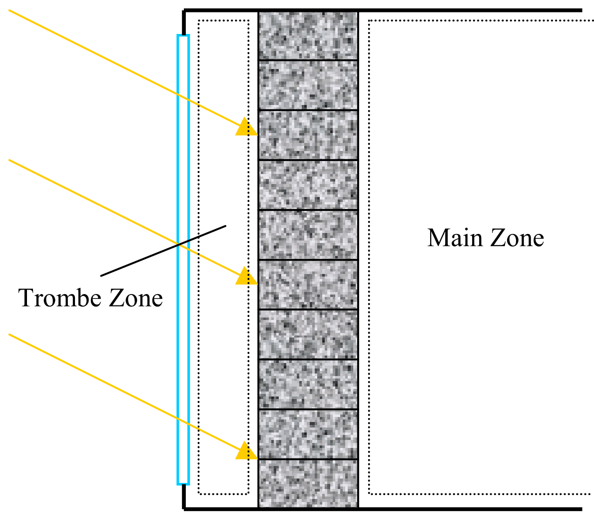

Figure 4. Trombe zone diagram.

The vented Trombe wall complicates matters by circulating air into the main zone. While a vented model is also implemented in EnergyPlus, it is beyond the scope of this thesis; only the unvented Trombe wall model is discussed.

3.2.1 Convection Coefficients

In the air gap of the unvented Trombe wall, convection occurs entirely by natural convection. Solar radiation transmitted through the glazing heats the wall surface while the glazing remains cooled by the outdoor environment. The difference in temperature establishes complex convection patterns inside the air gap, i.e. Trombe zone. The standard EnergyPlus interior convection correlations are intended for full-size rooms and no longer apply.

The type of convection inside the Trombe zone has been well-studied by other researchers and is referred to as natural convection in a cavity (also enclosure or channel) of high aspect ratio. Many empirical and numerical investigations have been reported. Hollands et al. (1976), Raithby et al. (1977), and ElSherbiny et al. (1982) are several frequently cited studies.

Heat transfer coefficients for natural convection are directly related to the Nusselt number.

$$Nu = \frac{h_c L}{k} \rightarrow h_c = \frac{kNu}{L}$$

The Nusselt number is correlated to the Rayleigh number and the Prandtl number.

$$Nu = f(Ra, \Pr)$$

The Rayleigh number based on the air gap spacing L is defined as:

$$Ra_L \equiv \frac{g\beta(T_1 - T_2)L^3}{\alpha\nu}$$

The Rayleigh number can alternatively be found in terms of the Grashof number.

$$Ra_L = \Pr Gr_L$$

The Grashof number is defined as:

$$Gr_L \equiv \frac{g\beta(T_1 - T_2)L^3}{\nu^2}$$

The Prandtl number for air is assumed to be sufficiently constant at 0.71 for the normal range of building temperatures.

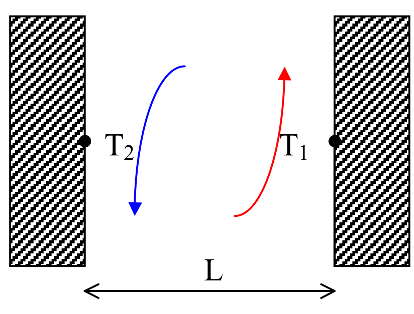

Figure 5. Convective heat transfer in a vertical cavity.

A review of the existing empirical correlations for the Trombe wall ultimately led to the decision to use a correlation already in use by EnergyPlus for windows. The correlation (ISO 15099 2000) determines the Nusselt number for convective heat transfer in the air gap of multi-pane windows, which also have a high aspect ratio. The advantage of the ISO 15099 correlation is that it is an accepted standard and accounts for different tilt angles.

The ISO 15099 correlation is a set of three different correlations depending on the tilt angle. In the following equations *a* is the aspect ratio *H*/*L*.

For vertical cavities, i.e. most Trombe walls, a correlation based on Wright (1996) is used:

$$Nu_1 = 0.0673838 Ra^{1/3} \qquad 5\text{x}10^4 < Ra < 10^6$$

$$Nu_1 = 0.028154 Ra^{0.4134} \qquad 10^4 < Ra < 5\text{x}10^4$$

$$Nu_1 = 1 + 1.7596678 x 10^{-10} Ra^{2.2984755} \qquad Ra \leq 10^4$$

$$Nu_2 = 0.242 \left(\frac{Ra}{a} \right)^{0.272}$$

$$Nu = Max(Nu_1, Nu_2)$$

For a 60 degree tilt a correlation by ElSherbiny, Raithby, and Hollands (1982) is used:

$$Nu_1 = \left[1 + \left(\frac{0.0936 Ra^{0.314}}{1+G} \right)^7 \right]^{1/7}$$

$$where: G = \frac{0.5}{\left[1 + \left(\frac{Ra}{3160} \right)^{20.6} \right]^{0.1}}$$

$$Nu_2 = \left(0.104 + \frac{0.175}{A} \right) Ra^{0.283}$$

$$Nu = Max(Nu_{1,} Nu_2)$$

The Nusselt number for tilt angles between 60 and 90 is found by interpolating between the above correlations.

For tilt angles below 60 degrees and $Ra<10^5$ and $a>20$, the correlation is (Hollands, Unny, Raithby, and Konicek 1976):

$$Nu = 1 + 1.44\left(1 - \frac{1708}{Ra\cos\theta}\right)^{\bullet}\left(1 - \frac{1708\sin^{1.6}(1.8\theta)}{Ra\cos\theta}\right) + \left(\left[\frac{Ra\cos\theta}{5830}\right]^{1/3} - 1\right)^{\bullet}$$

$$where: (x)^{\bullet} = (x + |x|)/2$$

The resulting Nusselt number is used to calculate the net convection coefficient from one surface to the other, $h_{c,net}$.

$$h_{c,net} = \frac{kNu}{L}$$

The net convection coefficient determines the total heat flux across the cavity.

$$q'' = h_{c,net}(T_1 - T_2)$$

In order to properly simulate the Trombe zone, convection coefficients between each surface and the zone air are required. To derive the convection coefficients for both interior surfaces, it is helpful to look at a thermal network analogy. The net convection coefficient is shown below as a simple resistive element.

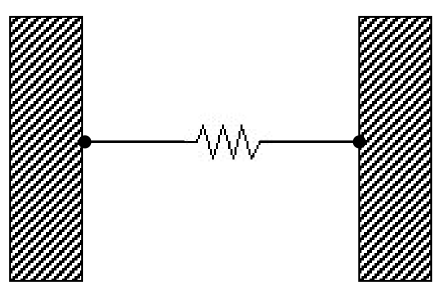

Figure 6. Thermal network diagram.

The net convective thermal resistance is:

$$R_{net} = \frac{1}{h_{c,net}A}$$

If both surfaces are to have a separate convection coefficient, the equivalent thermal network becomes:

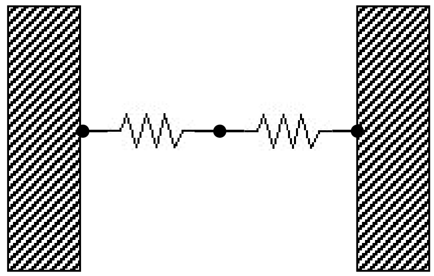

Figure 7. Equivalent thermal network diagram.

If the assumption is made that both resistances are equal to:

$$R = \frac{1}{hA},$$

it follows that $R_{net} = 2\,R$. Or:

$$\frac{1}{h_{c,net}A} = \frac{2}{h_c A}$$

Therefore,

$$h_c = 2h_{c,net}$$

One of the intentions of the validation is to determine if the ISO 15099 correlation and the above method of selecting convection coefficients is realistic and appropriate for Trombe walls. The theoretical validation section below addresses this question in part.

The remaining minor surfaces of the Trombe zone use the standard EnergyPlus interior convection correlation: ASHRAEDetailed. This is not expected to be accurate but should not greatly effect the net heat transfer because the minor surfaces only comprise a small proportion of the total zone surface area.

3.2.2 Interior Radiation Exchange

EnergyPlus does not calculate exact view factors for radiation exchange between interior surfaces in a zone. Instead, approximate view factors are calculated based on area and surface emissivity, and then "fixed" to meet requirements for reciprocity and completeness and radiation balance (EnergyPlus 2003). Approximate view factors are most accurate for zones that resemble a cube. As the zone aspect ratio departs from a cube, so does the accuracy of approximate view factors.

Since the Trombe zone has a very high aspect ratio, the accuracy of the approximate view factors should be verified. Exact view factors and approximate view factors for the Los Alamos Trombe zone geometry are compared below.

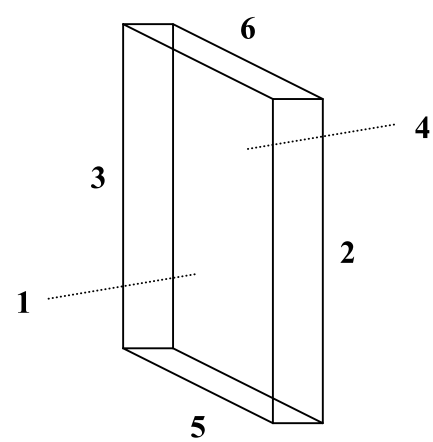

Figure 8. Trombe zone surfaces for view factors.

All approximate view factors are within 0.01 of the exact values. In this extreme case of very high aspect ratio, the major surfaces 1 and 4 show almost no error. These surfaces are also the most important because they have the largest areas and dominate the radiation exchange. The minor surfaces 2, 3, 5, and 6 show a small error, but contribute very little to the radiation exchange because of their small areas. Approximate view factors are very accurate for very high aspect ratio zones.

Although the validity of the approximate view factors for the Trombe zone has been established, the results of a simulation could still be in error if the adjoining zone has an unusual geometry. This, of course, is true with or without a Trombe wall coupled to the zone.

View Factor	*Exact*	*EnergyPlus*	*Error*
F_{11}	0.000	0.000	0.000
F_{21}	0.492	0.497	0.005
F_{31}	0.492	0.497	0.005
F_{41}	0.983	0.983	0.000
F_{51}	0.489	0.497	0.008
F_{61}	0.489	0.497	0.008
F_{12}	0.005	0.005	0.000
F_{22}	0.000	0.000	0.000
F_{32}	0.004	0.002	-0.001
F_{42}	0.005	0.005	0.000
F_{52}	0.010	0.002	-0.008
F_{62}	0.010	0.002	-0.008
F_{13}	0.005	0.005	0.000
F_{23}	0.004	0.002	-0.001
F_{33}	0.000	0.000	0.000
F_{43}	0.005	0.005	0.000
F_{53}	0.010	0.002	-0.008
F_{63}	0.010	0.002	-0.008
F_{14}	0.983	0.983	0.000
F_{24}	0.492	0.497	0.005
F_{34}	0.492	0.497	0.005
F_{44}	0.000	0.000	0.000
F_{54}	0.489	0.497	0.008
F_{64}	0.489	0.497	0.008
F_{15}	0.003	0.003	0.000
F_{25}	0.006	0.001	-0.005
F_{35}	0.006	0.001	-0.005
F_{45}	0.003	0.003	0.000
F_{55}	0.000	0.000	0.000
F_{65}	0.001	0.001	0.000
F_{16}	0.003	0.003	0.000
F_{26}	0.006	0.001	-0.005
F_{36}	0.006	0.001	-0.005
F_{46}	0.003	0.003	0.000
F_{56}	0.001	0.001	0.000
F_{66}	0.000	0.000	0.000

Figure 9. Comparison of exact and approximate view factors.

3.3 THEORETICAL VALIDATION

The complex nature of the Trombe wall model makes it difficult to engage in a comprehensive theoretical validation of the model. Some verification, however, can be made be independently by comparing the EnergyPlus convection correlation to other empirical correlations.

3.3.1 Convection Correlations

The unvented Trombe wall models in BLAST (Walton 1981) and DOE-2 (Moore et al. 1981) both use an empirical correlation that is referenced by Krieth (1973, 1976) and Jakob (1949), but originates from experimental work done by Mull and Reiher (1930). The correlation for turbulent flow is:

$$Nu = 0.065 Gr^{1/3} a^{-1/9}$$

$$2x10^5 \leq Gr \leq 1.1x10^7$$

$$10.6 < a < 42.2$$

Or, in terms of the Rayleigh number,

$$Nu = 0.065 \left(\frac{Ra}{\Pr} \right)^{1/3} a^{-1/9}$$

$$1.4x10^5 \leq Ra \leq 7.8x10^7$$

Another correlation comes from MacGregor and Emery (1969).

$$Nu = 0.42 Ra^{1/4} \Pr^{0.012} a^{-0.3}$$

$$10 < a < 40$$

$$1 < \Pr < 1000$$

$$10^6 < Ra < 10^7$$

The ISO 15099 correlation used in EnergyPlus and the two above are compared below for an aspect ratio of 42 (for the Los Alamos test cells) and Prandtl number of 0.71 for air.

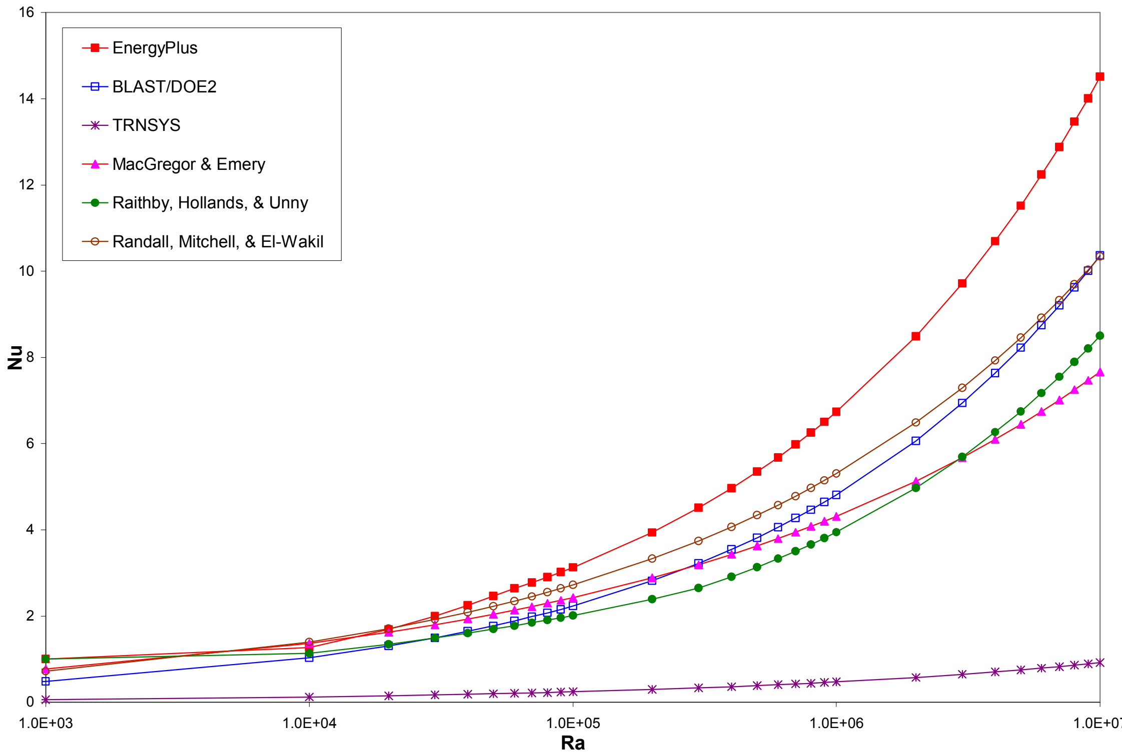

Figure 10. Comparison of convection correlations.

The problem of conflicting experimental results has been recognized by other researchers (MacGregor and Emery 1969). A possible explanation for the differences could be due to surface roughness effects. Roughness can increase the convection coefficient. The experimental literature is often unclear what surface materials are used.

Trombe walls with a selective surface can be expected to be nearly as smooth as glass and the ISO 15099 correlation should be suitable. Trombe walls with a masonry surface may be sufficiently rough to increase the convective heat transfer. In this case the ISO 15099 correlation may under predict the Nusselt number and convection coefficients. The effect of roughness should be investigated further.

The TRNSYS correlation seems very unlikely. The equation found in the program documentation does not clearly relate to the correlation described by Randall et al. (1979). The results found in the actual paper are much more consistent with the other correlations.

3.4 *EXPERIMENTAL VALIDATION*

To take into account the complexities of a building as a system, and the possibility of programming errors, a validation was undertaken to compare experimental data from Trombe test cells to EnergyPlus simulation results. The test cell data comes from the experiment conducted at Los Alamos during the 1981-82 winter. Cells 1 and 2 (see Figure 3) are the main object of the validation. Cell 1 is an unvented Trombe wall with a black painted surface and double pane glazing. Cell 2 is an unvented Trombe with a selective surface and double pane glazing.

The 1981-82 experiment represents the culmination of more than five years of test cell operation. Over the course of the experiments, different improvements were made to the test cells, and presumably the experimental technique was refined and mastered. The data set contains the greatest quantity of measured variables, and hopefully the greatest quality as well. The experiment was also the last of the series.

Due to the fact that twenty years have passed since passive solar test cell experiments were being performed in this country, it was difficult to find raw data for a Trombe wall test cell. The 1981-82 data set from Los Alamos was the only one available to the author. Unfortunately, the experiment is not ideally suited for a computer simulation validation. The main intent of the experiment was side-by-side comparison of the relative efficacy of various passive solar technologies. Consequently, emphasis was not on detailed measurements of every aspect of the test cells and environment. Notably missing are important measurements of material properties and the solar beam and diffuse radiation components.

Often, unknown variables are handled by "tuning" the values across a reasonable range until agreement is obtained. The decision was made to avoid this approach because it is rather arbitrary. Instead, a strategy was adopted to simulate two non-Trombe wall test cells as references for calibration of unknown variables. If the data could be calibrated for test cells that EnergyPlus should be able to simulate easily, then the unknowns are now known.

Cell 13, a reference cell with an opaque, insulated south wall, and cell 11, a direct gain cell, were selected as well-suited for calibration. Both cells are constructed of standard components that were expected to be easily simulated by EnergyPlus. Unknown variables can be calibrated using the simulation of these cells. The calibrated values can then be used in the Trombe wall simulation without resorting to arbitrary tuning of the Trombe wall cells. Ultimately, cell 11 and 13 were more difficult to simulate than expected.

To summarize, four test cells were selected for the validation:

- Cell 1: Trombe wall cell – black painted surface
- Cell 2: Trombe wall cell – selective surface
- Cell 11: direct gain cell
- Cell 13: reference cell

The reference cell is a closed room with no windows. The direct gain cell has a South-facing window with thermal storage bricks on the floor and lower part of the walls. One Trombe wall cell has a simple black painted surface while the other utilizes a selective surface.

Although cell 12 also contained a Trombe wall, it was not selected for the validation because it was being equipped with a convection suppression experiment during the validation period. Otherwise it was identical to cell 1.

The main goal of the validation is to match surface temperatures and globe temperatures for the selected cells. Globe temperature comparison gives a general measure of the success of the total building model. Surface temperatures are more specific, giving a slightly more localized validation. Comparing surface temperatures on both sides of the Trombe walls gives a good indication of the heat flux due to the wall, and is the most useful indication of the validity of the model.

3.4.1 Data Selection

Measured data from the 1981-82 experiment was available on microfilm. The data acquisition system recorded 179 channels of data for every hour between from January 12, 1982 to April 26, 1982. Data was sampled once every 20 seconds. An average and instantaneous value were recorded hourly. The measured data included both weather data and test cell data. Converting the microfilm data into digital format was a daunting task that could only be performed manually. It was clearly not practical to enter all of the data. A rationale for data selection had to be prescribed.

Because of the lack of independently measured solar beam and diffuse radiation, it was decided that clear sky days were a requirement. Hourly beam and diffuse radiation can be adequately generated by existing solar models for clear skies, but for non-clear skies.

Because of the significant thermal mass of the Trombe cells and direct gain cell, it was preferable to select as many clear sky days in a row as possible in order to develop a thermal history.

Fortunately, the task of locating sequential clear sky days was made infinitely easier by obtaining digital weather station data from the meteorological network at Los Alamos that was contemporaneous with the 81-82 experiment. Los Alamos maintains a network of weather stations to monitor climatic conditions in the event of a catastrophic release of toxic or radioactive chemicals from the laboratory (Baars et al. 1998).

Although two stations were in operation at the time, only one recorded solar radiation measurements. Located within approximately 7 km of the test cell site, the Area G weather station made measurements of total horizontal shortwave radiation. Although shortwave was measured instead of total solar radiation, the Area G measurements are still a good indication of prevailing solar conditions at the time. Unfortunately, the station measurements cannot be used to double-check the solar measurements made at the test cell site.

By visualizing the data as a carpet plot, it is possible to distinguish the clear sky days from the non-clear sky days.

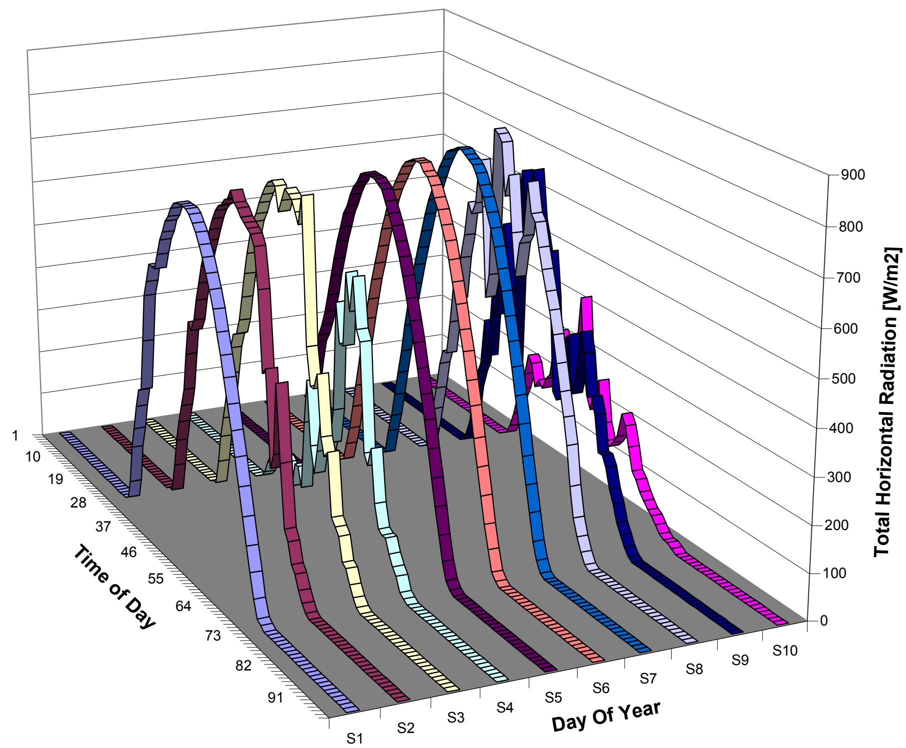

Figure 11. Total horizontal solar radiation for Feb. 15-24, 1982.

Over the duration of the experiment, at most three sequential clear days were found. The clearest days were found to be February 19, 20, and 21.

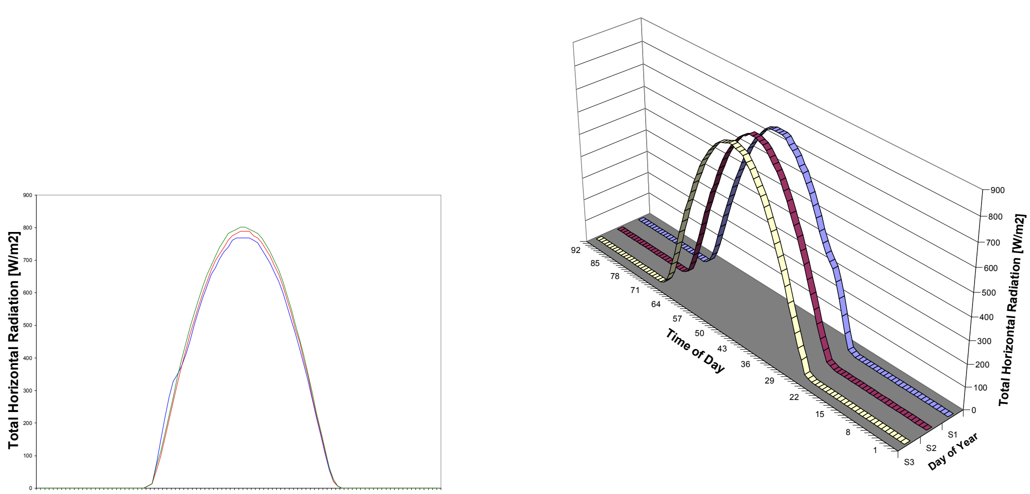

Figure 12. Total horizontal solar radiation for Feb. 19, 20, and 21, 1982.

Although it was not an ideally clear day, February 22 was added to extend the validation for six more hours. From 12 AM to 6 AM the sun is not yet up and non-solar weather data is expected to be reliable.

These three plus days were selected for the final validation. The relevant weather data and test cell data were subsequently input manually to a computer file.

3.4.2 Weather Data

All weather data was measured using a commercial weather station. The processing of weather data, and especially solar data, was undertaken with great care. These are the fundamental driving functions for the heat transfer phenomena in the test cells. The outdoor dry bulb temperature and the beam and diffuse solar radiation are the most important weather variables. The simulation is most sensitive to the outdoor dry bulb temperature and solar. Solar data is treated more extensively below.

3.4.2.1 Weather File

In order for weather data to be used by EnergyPlus, it must be processed into the proper weather file format for "in.epw".

Weather variables on-site were recorded as both an hourly average and an instantaneous measurement. The hourly average values were selected for use with the validation in order to eliminate any short-term fluctuations.

Although EnergyPlus can perform simulations using an hourly time step, it was decided to perform the validation using a ten minute time step. This is considered to be more accurate. The measured hourly average values were linearly interpolated. However, because EnergyPlus treats all weather file inputs as instantaneous values (when the weather file time interval is the same as the simulation time step), the hourly average values were shifted to the preceding half hour and interpolated from there.

Special attention was given to the interpolation of solar data near sunrise and sunset. After interpolation the data was manually adjusted to make sure no solar was received before sunrise or after sunset.

The minimum required EnergyPlus weather file variables and the experimentally measured variables are shown below with their respective units.

	EnergyPlus	*Experiment*	*Data Channels*
Dry bulb temperature	C	F	150/170
Dew point temperature	C	F	151/171, 159/179
Relative humidity	%	%	149/169, 154/174
Atmospheric pressure	Pa	---------- Not measured ----------	
Direct normal radiation	Wh/m2	---------- Not measured ----------	
Diffuse horizontal radiation	Wh/m2	---------- Not measured ----------	
Wind direction	degrees	degrees	158/178
Wind velocity	m/s	MPH	157/177

Figure 13. Weather variables.

Pairs of data channels indicate the hourly average and instantaneous measurements.

Outdoor dry bulb temperature, dew point temperature, relative humidity, wind direction, and wind velocity were all measured at the test cell site. The measured values were imported into the weather file after the units were converted and sub-hourly values were interpolated.

The raw weather data was somewhat confusing because there were two sets of relative humidities and two sets of dew point temperatures. The correct set of relative humidities (channel 149/169) was determined by comparing with the simultaneous measurements at the Area G station, and they were also the only ones that made sense, i.e. < 100%. The correct set of dew point temperatures (channel 159/179) was chosen because it was psychrometrically consistent with the dry bulb temperature and relative humidity.

Atmospheric pressure was not measured during the experiment. A constant value of 78,018 Pa was calculated for an altitude of 2,158 m by interpolating the table of values for the standard atmosphere (U. S. Standard Atmosphere 1962).

The direct and diffuse radiation was also not measured during the experiment. This is described in detail below.

3.4.2.2 Solar Radiation

As a passive solar device, the behavior of Trombe walls is sensitive to solar radiation. EnergyPlus requires solar radiation to be split into components: direct normal radiation, i.e. beam radiation, and diffuse horizontal radiation. Unfortunately, a pyrheliometer was not used to measure the beam component separately at the test site. Five Eppley PSP pyranometers were used to measure the total solar radiation at five different tilt angles facing south: 0, 36, 45, 60, and 90 degrees. Although the five pyranometers, with both average and instantaneous measurements, offer a lot of data, it is difficult to deduce the beam and diffuse components.

A comparison of the measured solar radiation at the horizontal pyranometer (0 degrees) to the instantaneous altitude angles calculated by EnergyPlus leads to a surprising conclusion.

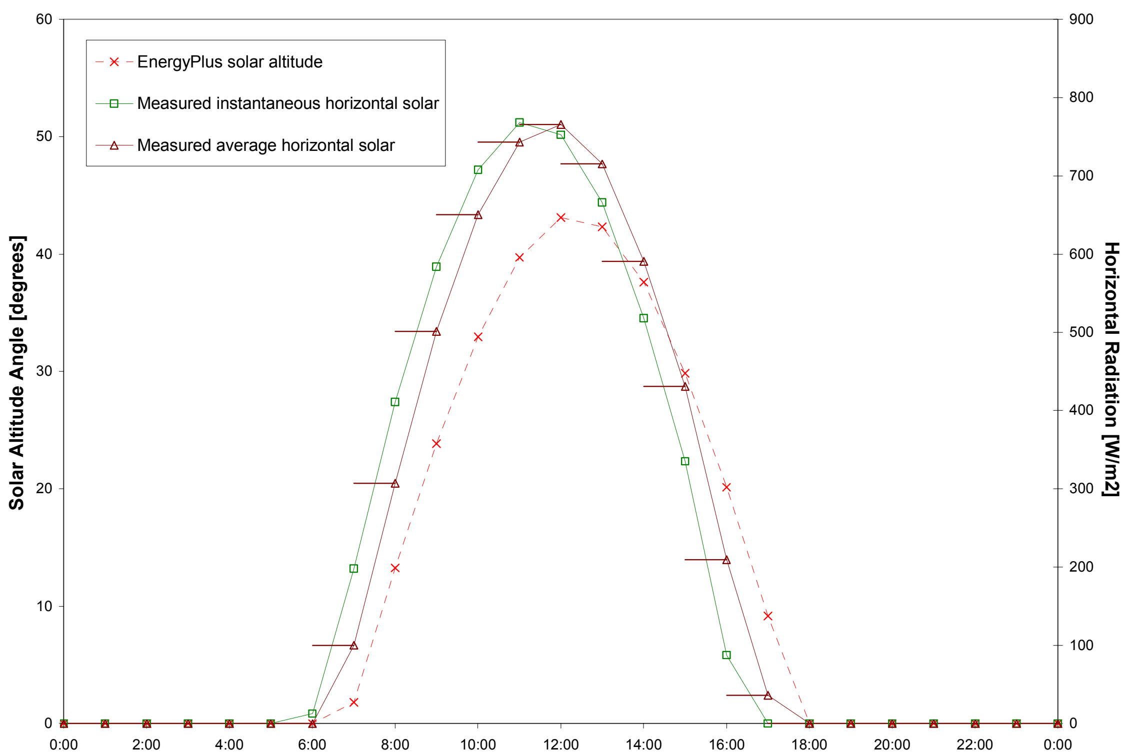

Figure 14. Comparison of measured horizontal solar and EnergyPlus altitude angle for Feb. 21, 1982.

It is apparent that neither the instantaneous or average pyranometer measurements are consistent with the instantaneous altitude angle. They should both peak at the same time. The other clear sky days in the validation period show the same result.

If the instantaneous pyranometer measurements are shifted one hour later, the agreement is more like expected.

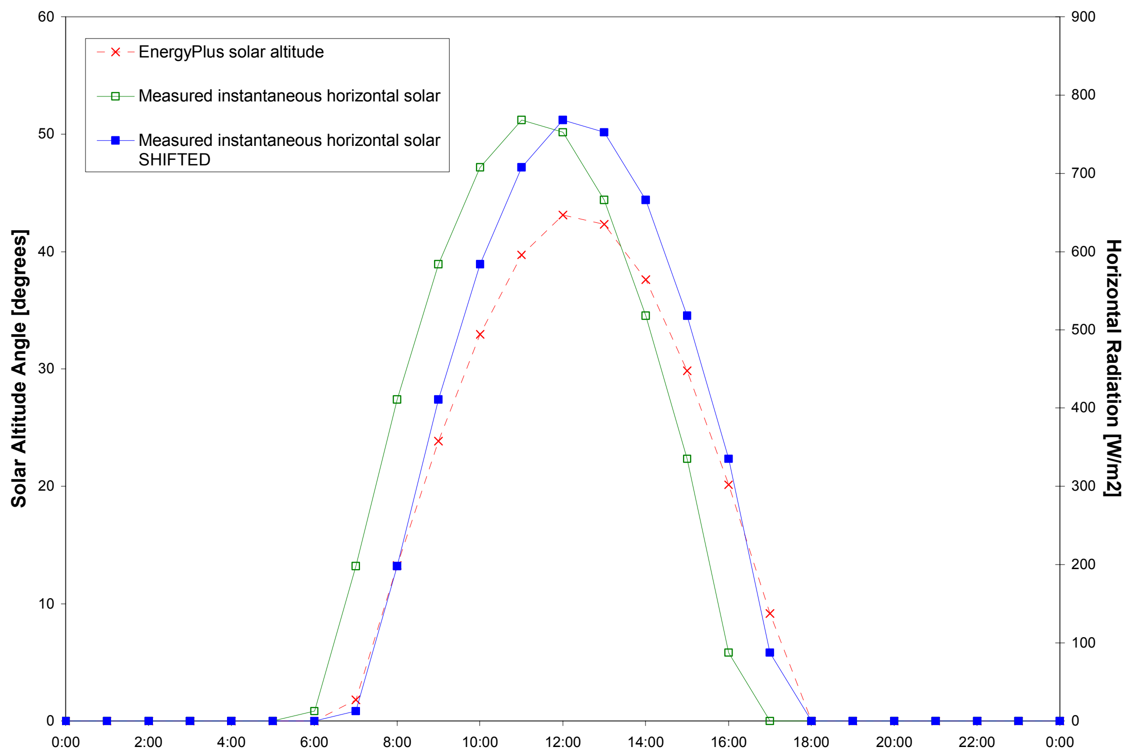

Figure 15. Comparison of shifted measured horizontal solar and EnergyPlus altitude angle, Feb. 21, 1982.

For additional verification the shifted values are also compared to the solar altitude angles calculated by another model (NOAA) and to the measured horizontal shortwave data recorded independently at the Area G weather station. The instantaneous pyranometer measurements at the other tilts are also consistent.

Since it seems unlikely that only the solar radiation data would be shifted, the instantaneous measured outdoor dry bulb temperature at the test cell site and the Area G weather station were also compared.

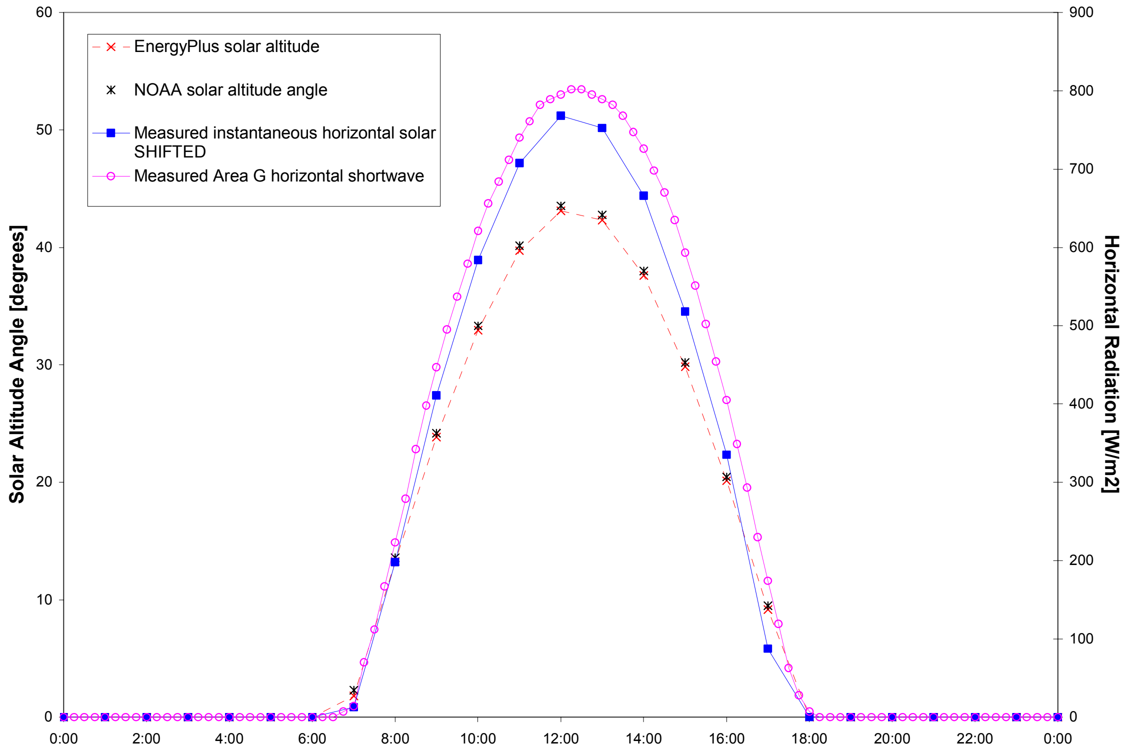

Figure 16. Comparison of altitude angles and measured horizontal radiation, Feb. 21, 1982.

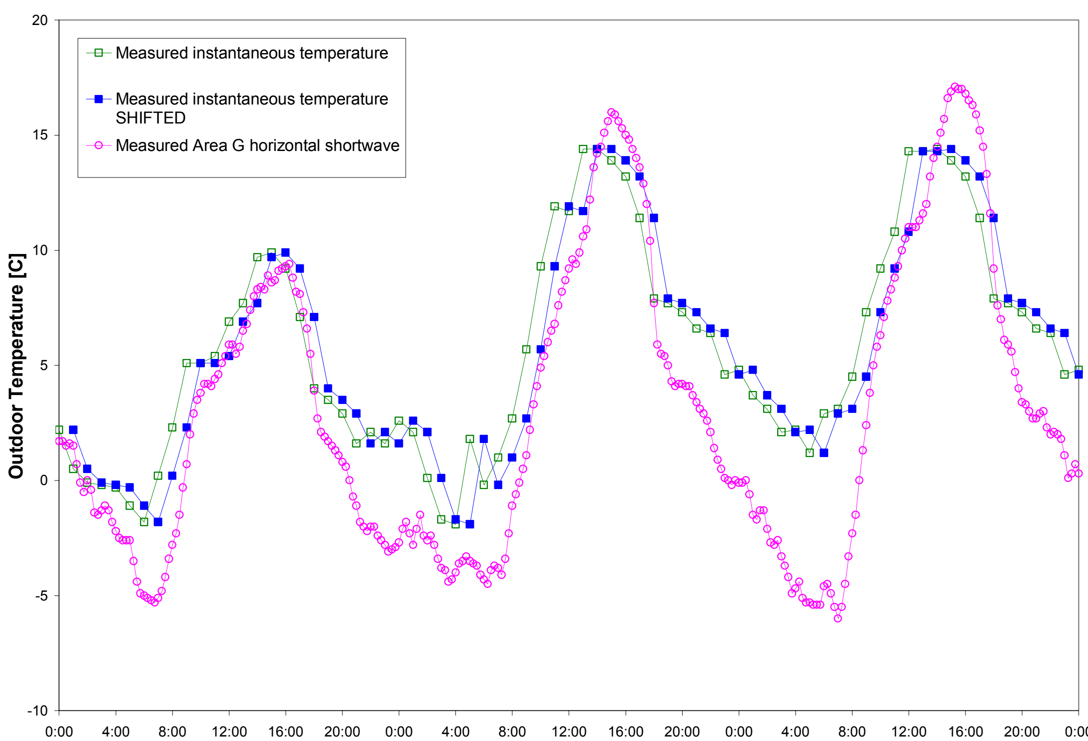

Figure 17. Comparison of instantaneous outdoor dry bulb temperature, Feb. 19-21, 1982.

The outdoor dry bulb temperature is more difficult to compare because the measurements were made at different locations and some variation is to be expected. Nonetheless, the shifted measurements appear to match the weather station better; the timing of the peaks and troughs coincides more closely.

The strong solar evidence and suggestive outdoor temperature data imply that there was an error in the data acquisition system. It is possible that it was as simple as the clock being set wrong. Whatever the explanation, all of the experimental data will be subsequently shifted one hour later for the remainder of the validation.

The approach taken to determine solar radiation was to use standard accepted clear sky models for beam and diffuse components. The high altitude of Los Alamos (2158 m) required that the models account for the effect of thinner atmosphere. At mountain elevations beam radiation is significantly stronger and diffuse radiation is weaker. Lower air density and reductions in water vapor and aerosols decreases the scattering of the solar beam (Barry 1981).

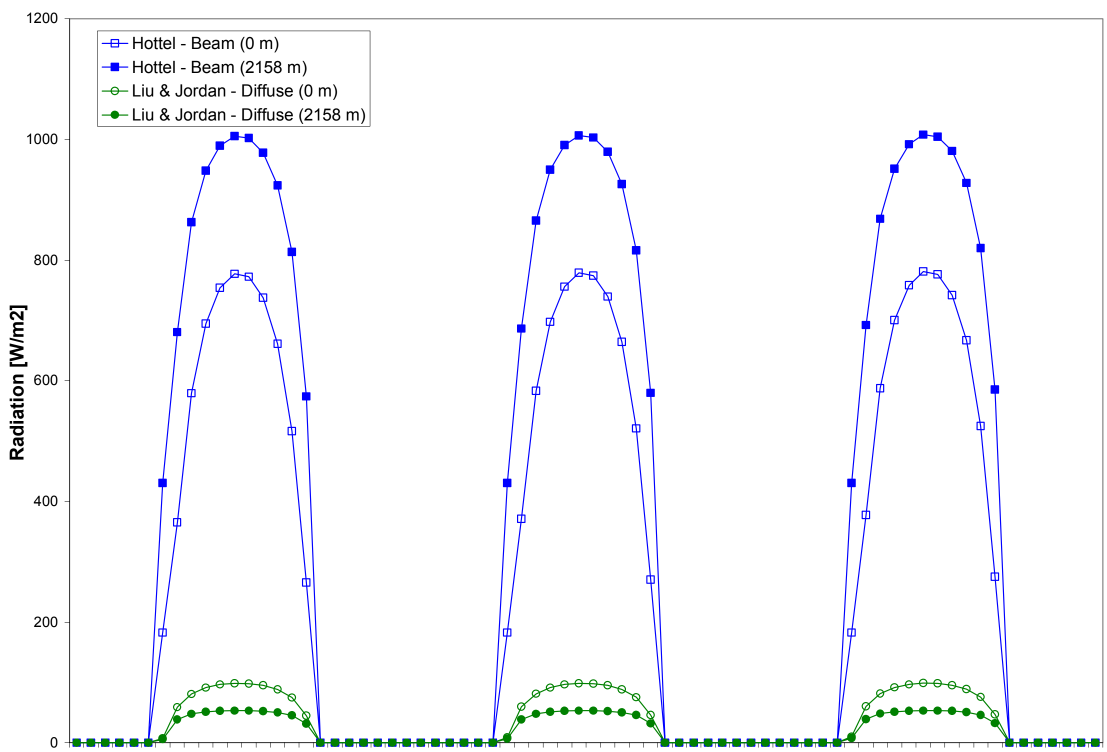

Figure 18. Modeled beam and diffuse solar radiation at 0 m and 2158 m, Feb. 19-21, 1982.

Hottel's model (Duffie and Beckman 1991) was adopted for clear sky beam radiation. Liu and Jordan's model (Duffie and Beckman 1991) was used for clear sky total horizontal diffuse radiation. Both models were plotted over the validation test dates for elevations of 0 m and 2158 m.

An alternative approach for determining solar radiation during the validation period is to treat the five pyranometers at the Los Alamos test site as a multi-pyranometer array. A multi-pyranometer array (MPA) is an instrument that uses an arrangement of three or more pyranometers oriented at different tilt and azimuth angles to effectively measure beam and diffuse components. The difference in the measured solar radiation at each pyranometer, combined with an anisotropic model of the sky radiance, makes this possible. Research has shown that MPAs can accurately measure the beam and diffuse components (Faiman 1993, Marion 1998).

An attempt to analyze the five pyranometer data as an MPA was unsuccessful. A major difference for the Los Alamos experiment is that all five pyranometers face south; each pyranometer of an MPA should face a different direction. Another discrepancy is that MPA pyranometers are generally shielded from ground radiation. The test site pyranometers receive as much as half of their radiation from the ground, in the case of the 90 degree tilt instrument.

3.4.3 Test Cell Data

Test cell data was entered from the microfiche and the units converted. The following variables were used:

	Units	*Data Channels*
Globe temperature	F	9, 19, 109, 129, 139
Trombe surface temperature: inside	F	3, 16
Trombe surface temperature: outside	F	1, 11
Direct gain cell floor	F	104
Direct gain shielded air temperature	F	107
Auxiliary heat	W	8, 18, 108, 128

Figure 19. Test cell data variables.

The globe temperature and surface temperatures were the primary means for comparing the simulation results to the experimental results.

3.4.3.1 Globe Temperature

The globe temperature inside of each test cell was measured using a black-painted toilet bowl float with a thermocouple inside. The globe sensor was located 6 feet off the ground (about two-thirds of the cell height) in the center of the cell. It was not exposed to direct sunlight. The globe sensor measures the combined effects of the zone air temperature and mean radiant temperature. For comparison to the EnergyPlus data, it is approximated as the average of the two.

3.4.3.2 Surface Temperatures

Select surface temperatures in the test cells were measured using thermocouples. The Trombe wall test cells had sensors mounted on the Trombe wall at several heights and embedded at several depths in the wall concrete. The direct gain cell had sensors mounted on and embedded in the concrete of the floor.

3.4.3.3 Auxiliary Heat

Heat was added to the main zone of each test cell by turning on and off several incandescent light bulbs. The bulbs were controlled at a set point temperature and the amount of power supplied to the bulbs was measured.

The auxiliary heat is an important variable because it is an immediate internal load that greatly effects the test cell temperatures. Like a weather variable, it is a driving force. The auxiliary heat was measured as the average over the previous hour.

3.4.3.4 Ventilation

The test cells were ventilated with outside air using a small fan. The air passed through a flow-straightening section and nozzle before diffusing across a deflector plate. Although not exactly a variable because it was constant throughout the experiment, the volumetric flow rate was an important physical parameter for the simulation. The volumetric flow rate was checked and adjusted weekly using an inclined manometer.

3.4.4 Test Cell Input Files

A separate EnergyPlus input file was created for each test cell. All cells had the same geometry and construction with the exception of the south wall. The passive solar device occupied the south wall, except for the reference cell which had no device. The cells faced true south within a 0.5 degree. Each cell was relatively small with a floor area of roughly 3.5 m^2. The cells were made of a lightweight construction and heavily insulated. Each pair of cells shared an insulated interior wall.

The exterior walls were exposed to wind and sun, except for shading due to neighboring test cells. The cell floor was elevated from the ground by risers to reduce the uncertainty of ground heat transfer (although this exposed the floor to outside air and wind).

A small fan system pressurized each test cell to minimize infiltration. The fan system ventilated the cells with outside air at rate of 3 air changes per hour. Auxiliary heat, consisting of two 500 W incandescent light bulbs, was used to maintain a set-point temperature of 18.3 C.

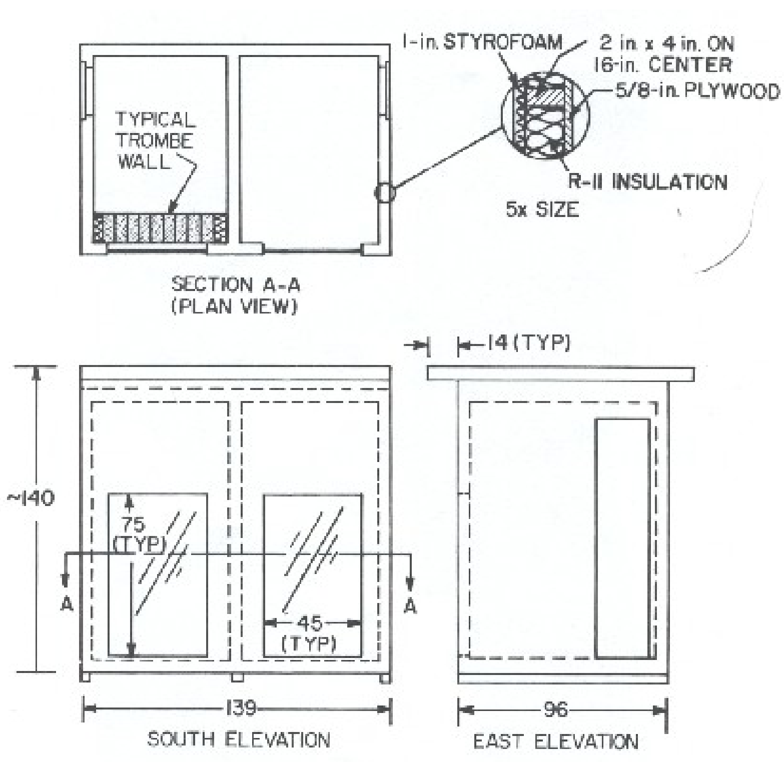

Figure 20. Test cell geometry.

The construction and material properties used in the input files are described in detail for each test cell below.

Cell 1 - Trombe Wall	
Dimensions (W x L x H)	1.6 m x 2.2 m x 3 m
South window construction	3/16" glass pane (2.2 m^2 area) 1/2" air gap 3/16" glass pane (2.2 m^2 area)
South wall construction	15 5/8" concrete block - painted black
Exterior wall construction	5/8" plywood - painted white 3 1/2" fiberglass batt insulation 1" styrofoam insulation
Interior wall construction	1" styrofoam insulation 3 1/2" fiberglass batt insulation 1" styrofoam insulation
Roof construction	roofing materials 5/8" plywood 7" fiberglass batt insulation 1/16" corrugated metal 1" styrofoam insulation
Floor construction	1/4" plywood 7" fiberglass batt insulation 5/8" plywood
Thermal mass	south wall, 99 bricks at 53 lbs each
Ventilation	3 ACH = 0.006655 m^3/s
Auxiliary heat	read from "in.dat" file

Figure 21. Summary of EnergyPlus input file description for cell 1.

The air gap spacing between the glazing and the wall surface were not explicitly stated in the Los Alamos reports. Design guidelines given in the *Passive Solar Design Handbook* (Anderson et al. 1980), suggest a spacing between 3" to 4". A spacing of 2" was selected after consulting with one of the original Los Alamos researchers (Balcomb 2003). In actuality, results are very similar in the range of 2" to 4".

Cell 2 - Trombe Wall	
Dimensions (W x L x H)	1.6 m x 2.2 m x 3 m
South window construction	3/16" glass pane (2.2 m^2 area) 1/2" air gap 3/16" glass pane (2.2 m^2 area)
South wall construction	copper/black chrome selective surface 1/4" Sur-Wall® plaster 15 5/8" concrete block
Exterior wall construction	5/8" plywood - painted white 3 1/2" fiberglass batt insulation 1" styrofoam insulation
Interior wall construction	1" styrofoam insulation 3 1/2" fiberglass batt insulation 1" styrofoam insulation
Roof construction	roofing materials 5/8" plywood 7" fiberglass batt insulation 1/16" corrugated metal 1" styrofoam insulation
Floor construction	1/4" plywood 7" fiberglass batt insulation 5/8" plywood
Thermal mass	south wall, 99 bricks at 53 lbs each
Ventilation	3 ACH = 0.006655 m^3/s
Auxiliary heat	read from "in.dat" file

Figure 22. Summary of EnergyPlus input file description for cell 2.

The selective surface was a copper foil with black chrome plating. It was adhered to the concrete blocks using a masonry plaster called Sur-Wall® because the 1980-81 selective surface had suffered from a poor thermal connection to the wall.

Most material properties were not measured for the test cells. Nominal values were assumed based on the EnergyPlus materials database. Where experimentally measured values were available, they were used instead.

The thermal conductivity of the fiberglass insulation was calculated from the nominal R-value of 11 for the 3.5 inch thickness. This value was ultimately modified during calibration of the reference test cell data.

Cell 11 - Direct Gain	
Dimensions (W x L x H)	1.6 m x 2.2 m x 3 m
South window construction	3/16" glass pane (2.2 m^2 area) 1/2" air gap 3/16" glass pane (2.2 m^2 area)
South wall construction	5/8" plywood - painted white 4 1/2" styrofoam insulation
Exterior wall construction	5/8" plywood - painted white 3 1/2" fiberglass batt insulation 1" styrofoam insulation 5 5/8" concrete block - painted brown (only part way up the walls)
Interior wall construction	1" styrofoam insulation 3 1/2" fiberglass batt insulation 1" styrofoam insulation 5 5/8" concrete block - painted brown (only part way up the wall)
Roof construction	roofing materials 5/8" plywood 7" fiberglass batt insulation 1/16" corrugated metal 1" styrofoam insulation
Floor construction	1/4" plywood 7" fiberglass batt insulation 5/8" plywood 5 5/8" concrete block - painted brown
Thermal mass	floor and part way up the walls, 99 bricks at 53 lbs each
Ventilation	3 ACH = 0.006655 m^3/s
Auxiliary heat	read from "in.dat" file

Figure 23. Summary of EnergyPlus input file description for cell 11.

Cell 13 - Reference	
Dimensions (W x L x H)	1.6 m x 2.2 m x 3 m
South window construction	*none*
South wall construction	5/8" plywood - painted white 4" styrofoam insulation
Exterior wall construction	5/8" plywood - painted white 3 1/2" fiberglass batt insulation 1" styrofoam insulation
Interior wall construction	1" styrofoam insulation 3 1/2" fiberglass batt insulation 1" styrofoam insulation
Roof construction	roofing materials 5/8" plywood 7" fiberglass batt insulation 1/16" corrugated metal 1" styrofoam insulation
Floor construction	1/4" plywood 7" fiberglass batt insulation 5/8" plywood
Thermal mass	*none*
Ventilation	3 ACH = 0.006655 m^3/s
Auxiliary heat	read from "in.dat" file

Figure 24. Summary of EnergyPlus input file description for cell 13.

Material	k	ρ	c_p	ε_{therm}	α_{solar}	α_{vis}	τ_{solar}
concrete block - brown	****1.385**	***2189**	****510**	0.90	***0.87**	***0.87**	
concrete block - black	****1.385**	***2189**	****510**	0.90	0.95	0.95	
SurWall plaster	0.72	1858	830	0.90	0.20	0.20	
selective surface	392.6	8906	370	***0.07**	***0.92**	0.92	
plywood	0.115	545	1213	0.90	0.70	0.70	
plywood - white	0.115	545	1213	0.90	0.25	0.25	
fiberglass batt	0.0459	84.8	963	0.90	0.50	0.50	
styrofoam	0.0305	28.8	1213	0.80	0.50	0.50	
corrugated metal	45.3	7833	502	0.20	0.23	0.23	
glass pane	0.90			0.84			***0.83**

*** = experimentally measured, ** = determined by Goldstein (1978)**

Figure 25. Material properties for EnergyPlus input files, all test cells.

The density of the concrete block was calculated from the weight and dimensions specified in the Los Alamos report. The thermal conductivity and specific heat of the concrete block were analytically determined by Goldstein (1978) and found to be considerably different from the nominal values given in the report. The Goldstein properties were used for the validation. They are compared in the analysis section below.

3.4.4.1 Adjoining Cells

Although the interior wall separating adjoining test cells in each test building was insulated, large temperature differences between cells because of different passive solar technologies were a concern. For instance, direct gain cell 11 had very large temperature swings, but the adjoining Trombe cell 12 did not. The interior wall was modeled using the "Other Side Coefficient" object in EnergyPlus. The measured globe temperature from the adjoining cell was used to set the other side boundary condition.

3.4.4.2 Ventilation

Ventilation was accomplished in the input file using a fan and outside air system. The system volumetric flow rate was based on the reported air changes per hour.

$$\dot{V} = \frac{ACH * V}{3600}$$

For the nominal 3 ACH, the flow rate is 0.00875 m^3/s. Because the fan pressurizes the cell, infiltration is assumed to be negligible.

3.4.4.3 Shading

Shading surfaces were added to account for shadows cast by neighboring test cells, i.e. cell 2 was shaded by cell 3 from the west. Cell 1 was the only one without any shading.

The distance between test cells was estimated by analyzing the digitized photo of the test cells (Figure 2). Using a ratio of the number of pixels between neighboring test cells to the number of pixels of a known distance, such as the test cell width, the distance was calculated to be 1.37 m.

Because Los Alamos is located in the mountains of New Mexico, topographical maps of the area were consulted to determine any possible shading effect due to mountain ranges. To the west the mountains increase in elevation. The nearest mountain range was estimated at a height of 600 m and a distance of 7000 m relative to the test cell site. At that distance the hemisphere of the sky is obscured by less than 5 degrees, or roughly 20 minutes of sunset. This was considered to be sufficiently insignificant for the simulation and no additional shading was added.

3.4.4.4 Thermal History

Given the substantial quantity of concrete in the Trombe and direct gain cells, transient thermal history effects were predicted to be important. In many cases passive solar buildings rely on the storage effect of thermal mass.

EnergyPlus begins each simulation by "warming-up" the building using the first day of weather data. With all surfaces initialized to the same temperature, the first day is simulated repeatedly until the surface temperatures converge to a steady-periodic heat balance.

While this approach is appropriate for a design day simulation, it is not appropriate for an experimental validation with significant thermal mass. In an actual experiment the thermal history is established by the changing daily weather conditions. For example, several cold days in a row have the effect of storing coldness in the thermal mass. If the EnergyPlus simulation begins on the following day, which happens to be much warmer, the program has no data abut the cold days. The warm-up days make it appear that the previous days had all been warm. In such a worse case scenario, it is possible to have large discrepancies between simulated and experimental results.

To determine the test cell sensitivity to thermal history, the transient temperature change of the direct gain cell was analyzed with the exponential decay equation:

$$T(t) = (T_0 - T_\infty)e^{-t/\tau}$$

The time constant τ is the time that it takes for the temperature $T(t)$ to get within approximately 36.8% of the final temperature T_∞. The theoretical time constant is calculated by making an estimate of the mass, specific heat, and total thermal conductance of the test cell.

$$\tau = \frac{mc_p}{UA_{tot}}$$

As designed, the concrete bricks constitute the vast majority of the test cell thermal mass. The total mass of the concrete alone is 2,380 kg (more than 2 tons!). The specific heat for the concrete is from Goldstein (1978). The total thermal conductance of the test cell is given by:

$$UA_{tot} = BLC + UA_{southwall} + UA_{window}$$

BLC is the building load coefficient of the test cell without considering the south face. All the test cells have a theoretical *BLC* of 13.7 W/K which was confirmed experimentally (McFarland 1982). Adding terms for the wall and window conductance, the total thermal conductance for the direct gain cell is calculated to be 19.9 W/K. The resulting time constant is about 17 hours.

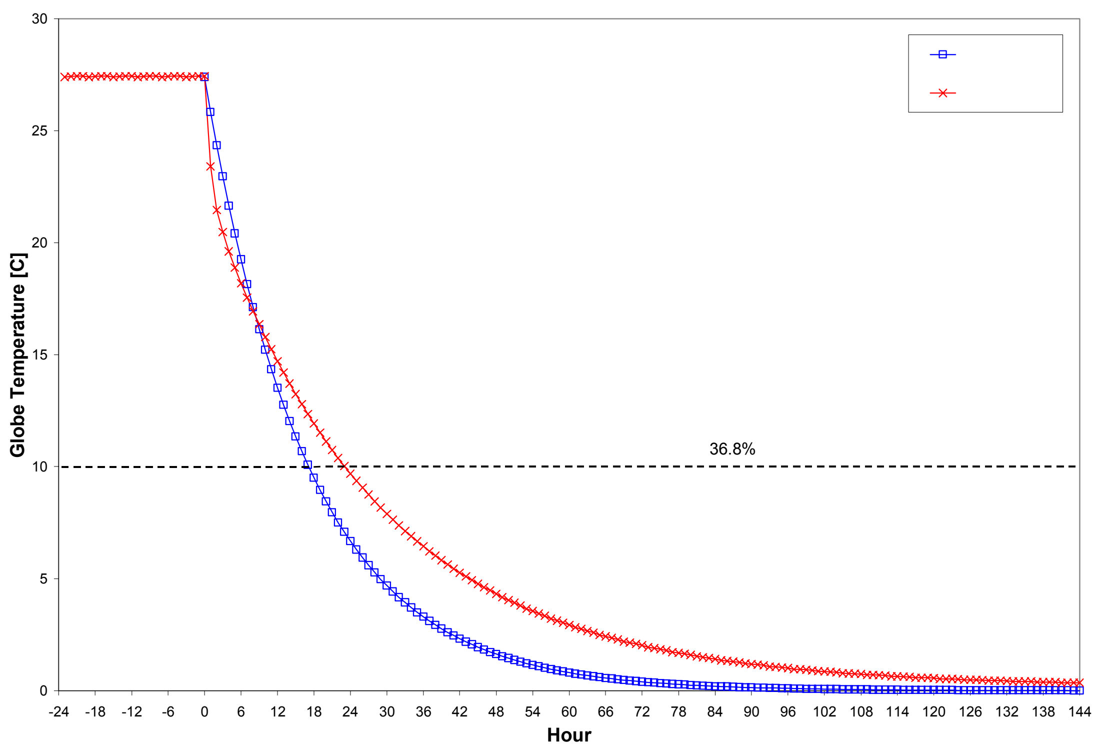

Figure 26. Comparison of exponential test cell heat loss.

A virtual experiment was performed with EnergyPlus to measure the effective time constant during simulation. Artificial steady-state exterior conditions were imposed on the cell during warm-up. After warm-up the outdoor temperature is changed from 30 C to 0 C and the inside temperature is observed to decay exponentially as heat is lost from the building mass.

The time constant for the EnergyPlus simulation is 23 hours. This value may be greater than the theoretical time constant because the program takes into account all of the building mass. The theoretical value was only calculated for the concrete.

After 23 hours the temperature is within 36.8% of the final temperature. To get within 2% of the final temperature, it takes 120 hours or five days. That means it takes five days of thermal history to wash out a very large change in temperature (~30 C). Since the test cells typically experience temperature changes of roughly 15 C at most, five days should be more than adequate for the experimental validation. Weather and test cell variable data was added for the five days preceding the three selected clear sky days, making the extended validation period February 14-22.

3.4.5 EnergyPlus Modifications

To allow the validation to be as successful as possible, several modifications were made to a development version of the EnergyPlus source code. Certain measured data was used as an input to the program to eliminate as many unknowns as possible. The data was read in from an external file named "in.dat". The following variables were read from the file:

- auxiliary heat for cells 1, 2, 11, 13
- globe temperature for cells 1, 2, 11, 12, 13, 14
- surface temperatures for cells 1, 2, 11, 13

Each of the variables was measured hourly during the experiment. The processing of the "in.dat" file worked very much like the EnergyPlus weather file "in.epw". The program interpolated the variables as necessary, or they could be interpolated manually beforehand.

The auxiliary heat variable was hard-coded to set the internal heat gain rate for each cell. This was used throughout the simulation. The standard EnergyPlus "Lights" object was used as to define the radiative/visible/convective split. From BLAST data, the split for incandescent light bulbs was assumed to be 0.7/0.1/0.2. Each test cell contained two 500 W bulbs controlled by the globe sensor at a set point of 65 F. The actual power was read in from "in.dat".

The globe temperature variables were used to hard-code the zone air temperature of the adjoining test cell for the calculation of the other side coefficients. These were also used throughout the simulation. Although not extremely influential for the results, they were originally thought to be significant in the cases where there was a significant temperature difference between adjoining test cells.

The surface temperature variables were hard-coded into the inside surface heat balance only during the first five days of the simulation. The intention was to force the surface temperatures that were measured to help establish an accurate thermal history before allowing the surfaces to participate in the heat balance normally during the last three days of the simulation.

3.4.6 EnergyPlus Simulation Results

The reference cell and direct gain cell were simulated extensively to calibrate the unknown physical parameters and understand the general heat transfer phenomena. Globe temperature was the primary means of assessing the agreement of the simulation with the experimental data.

The two Trombe wall cells were subsequently simulated with the calibrated values. Surface temperatures on either side of the wall were the primary indication for validity of the model. Reasonable surface temperatures imply that the heat flux through the wall is accurate, and therefore, the direct contribution of the Trombe wall is correct.

A 10 minute time step was used for all simulations. Hourly data was interpolated as described above.

3.4.6.1 Calibration

The simplest test cell, the reference cell, was calibrated first. The unknown parameters were the thermal conductivity of the styrofoam and fiberglass insulation. Preliminary analysis showed that the test cell was also very sensitive to the ventilation rate and the exterior solar absorptance, i. e. exterior color. The ventilation rate was not considered for calibration because it was one of the few variables actually measured. The calibrated parameters were:

Parameter	*Nominal*	*Calibrated*
Thermal conductivity, styrofoam (W/m K)	0.036	0.025
Thermal conductivity, fiberglass (W/m K)	0.043	0.040
Exterior solar absorptance	0.30	0.25

Field 27. Reference cell calibration parameters.

Oddly, calibration tended to change the parameters in the wrong direction from the nominal values. The exterior becomes "whiter" and the insulation becomes less conductive. This is usually the opposite of what is expected. The results are shown below.

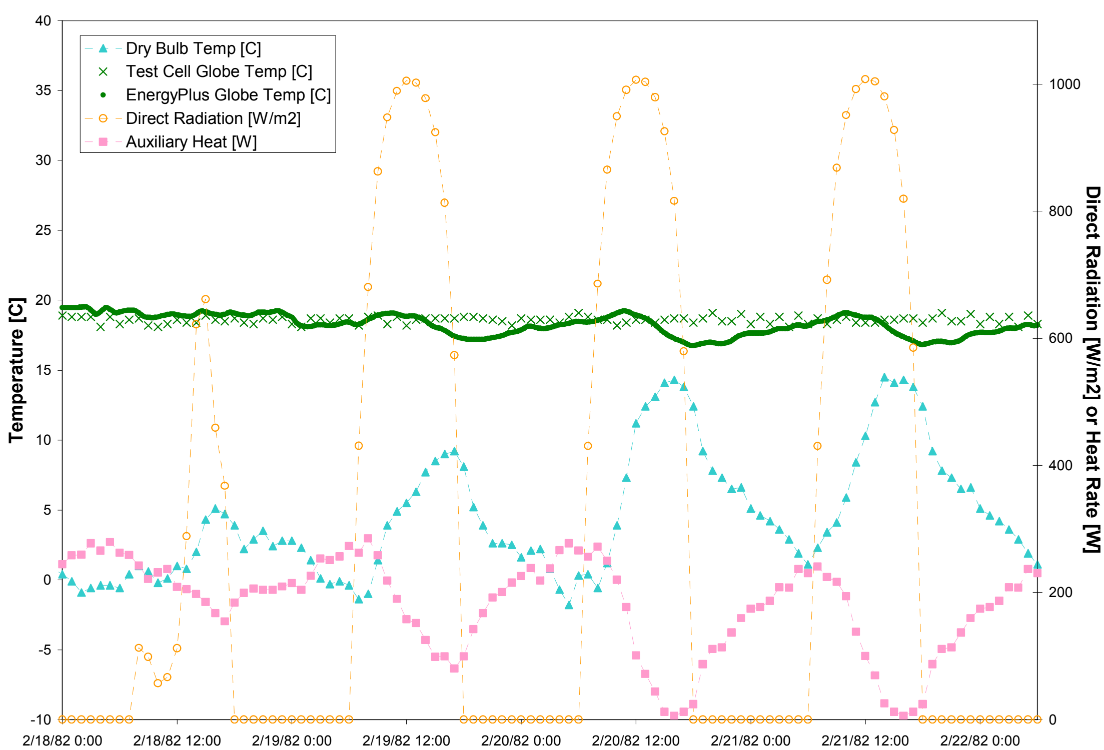

Figure 28. Reference cell globe temperature comparison, Feb. 18-22.

The simulated globe temperature agrees well with the experimental data, although there were lingering fluctuations.

When comparing simulated and experimental globe temperature, it should be kept in mind that EnergyPlus does not calculate an actual globe temperature. EnergyPlus only calculates the zone air temperature and mean radiant temperature. The globe temperature lies somewhere between the air temperature and mean radiant temperature. The two temperatures are averaged as an approximation.

There is also an inconsistency in the longwave radiation striking the globe sensor compared to the mean radiant assumption. Mean radiant temperature is calculated for a point at the center of the zone. The globe sensor was located at the center, but two-thirds of the way up to the ceiling. Consequently, the globe sensor was preferentially measuring the radiant temperature of the ceiling over the other surfaces.

The direct gain cell was simulated with the thermal conductivity values calibrated for the reference cell. The direct gain cell was not sensitive to the exterior solar absorptance. Preliminary analysis showed high sensitivity to the ventilation rate, as above, but also to the window glass transmissivity. Like the ventilation, the glass transmissivity was a measured property and was not calibrated.

The results were also sensitive to the material properties of the concrete brick. Nominal values of thermal conductivity and specific heat were given in the Los Alamos report. Goldstein (1978) presents an analysis of the data that demonstrates that the actual properties are significantly different.

Parameter	*Nominal*	*Goldstein*
Thermal conductivity, concrete (W/m K)	1.73	1.39
Specific heat, concrete (J/kg K)	797	510

Figure 29. Direct gain cell concrete properties.

The globe temperature results for both the nominal and Goldstein properties are shown below.

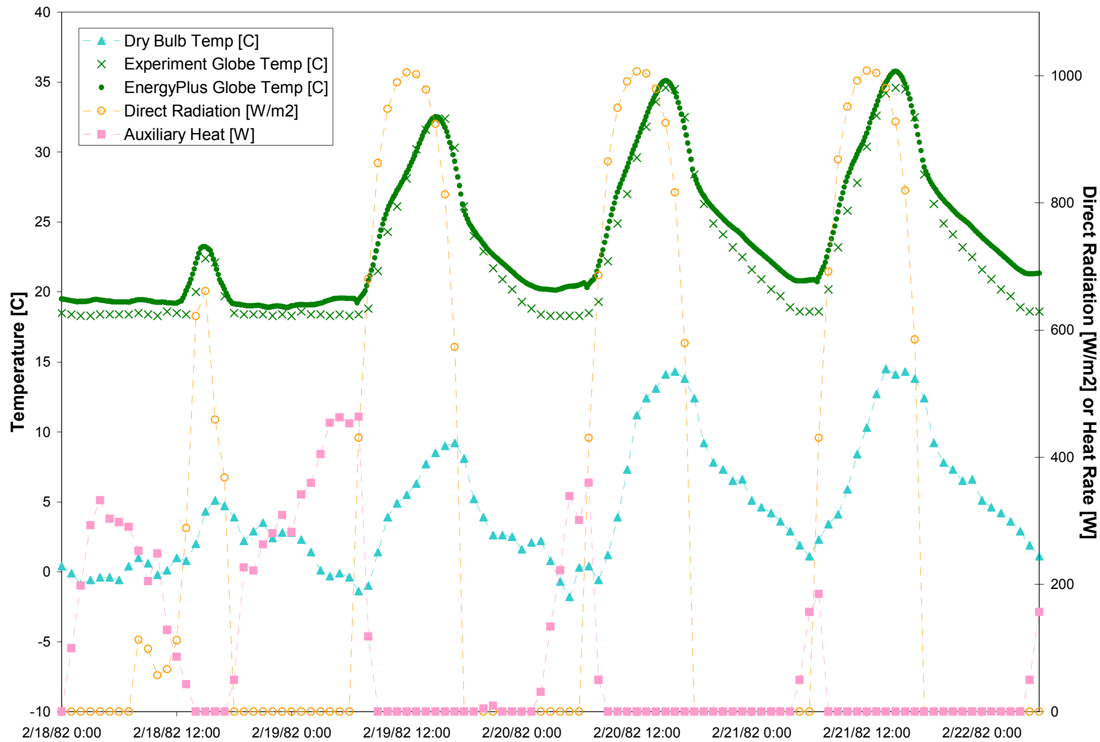

Figure 30. Direct gain cell globe temperature comparison with nominal properties, Feb. 18-22.

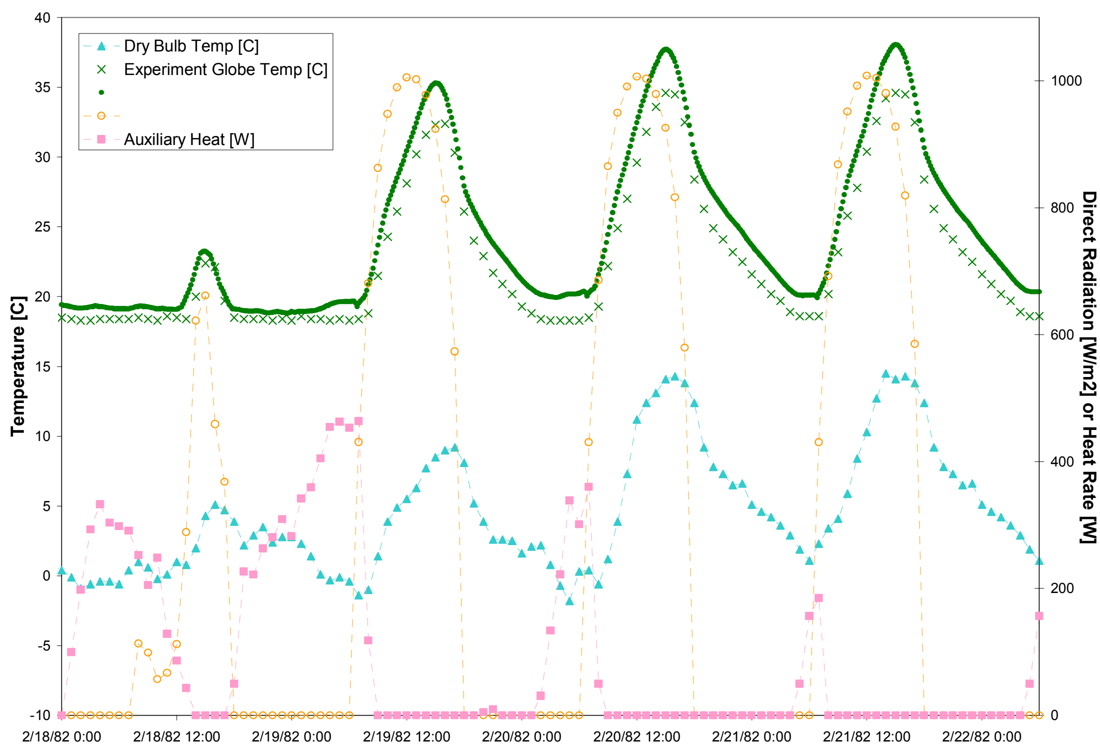

Figure 31. Direct gain cell globe temperature comparison with Goldstein properties, Feb. 18-22.

The Goldstein properties clearly improve the slope of the globe temperature decay in the night hours. The overall shape of the curve agrees extremely well although the peak is now a little higher.

The floor surface temperature is compared below using the Goldstein properties.

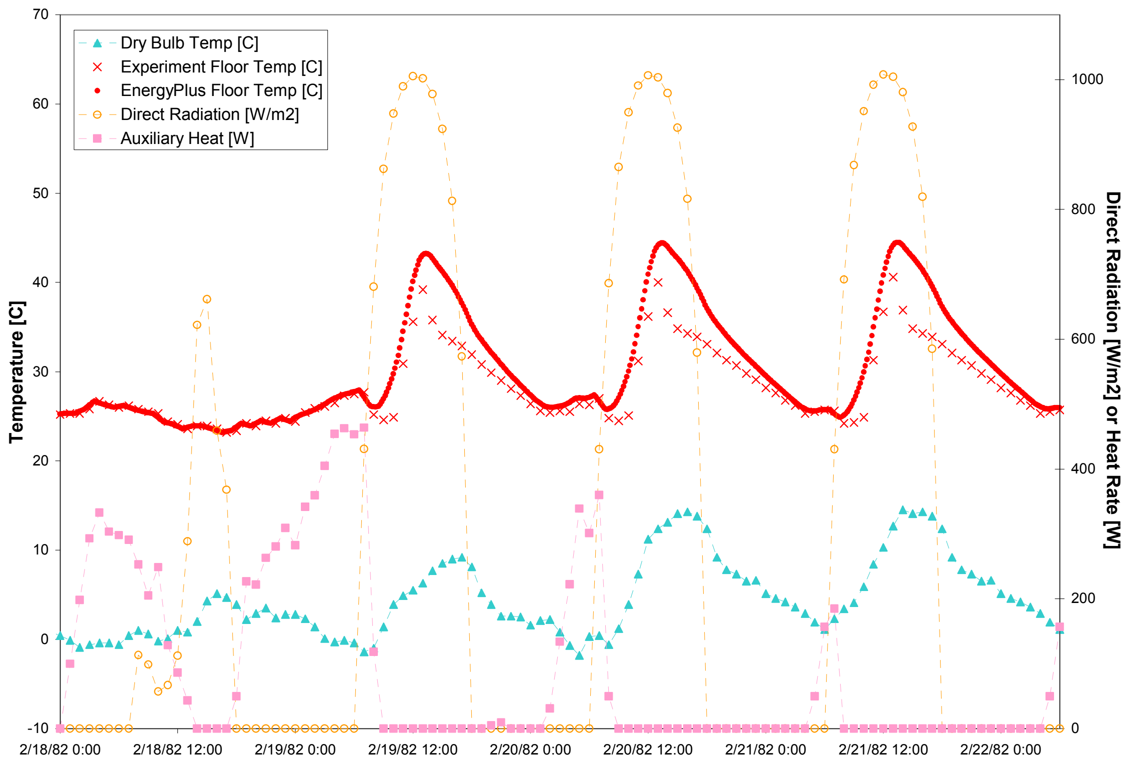

Figure 32. Direct gain cell floor temperature comparison, Feb. 18-22.

The floor surface temperature shows some significant variations in shape. This may be a result of comparing local and average surface temperatures. The experimentally measured temperature is from a thermocouple positioned on the top center of the floor. The EnergyPlus surface temperature is an average temperature for the entire top face. Direct solar beam striking the thermocouple could perhaps be the cause of the spike in temperature at noon. It is encouraging, however, that the peaks and troughs occur at the same times.

3.4.6.2 Validation

The Trombe wall test cells were simulated with the calibrated parameters from the reference cell and direct gain cell; no further calibration or "tuning" was done to the input files. The globe temperature and surface temperature results for both Trombe wall cells are shown below.

"N Face Temp" and "S Face Temp" refer to the surface temperature on the north and south faces of the Trombe wall respectively. The north face is inside the main zone. The south face is in the Trombe air gap. The experimental surface temperature data are measurements from a thermocouple located on the face of the wall at midheight. The EnergyPlus surface temperatures are an average temperature for the entire face.

The globe temperature comparisons in Figures 33 and 35 show remarkable agreement between simulation and experiment for both Trombe wall test cells. The shape and magnitude match very well.

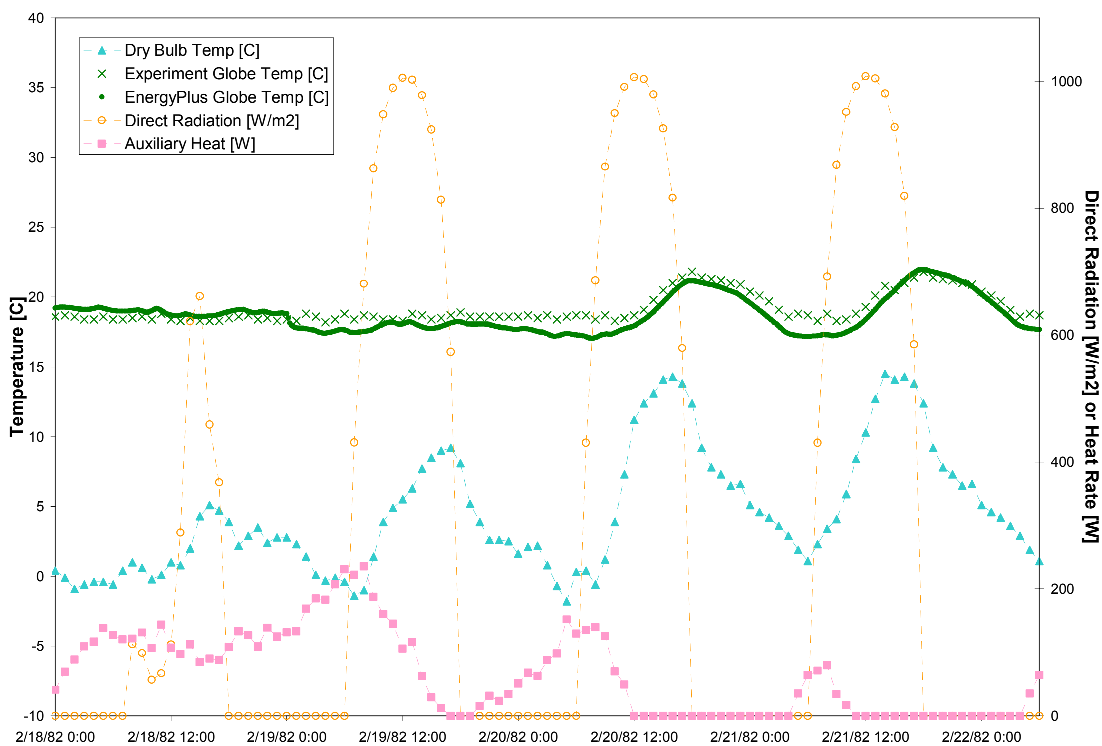

Figure 33. Painted Trombe wall cell globe temperature comparison, Feb. 18-22.

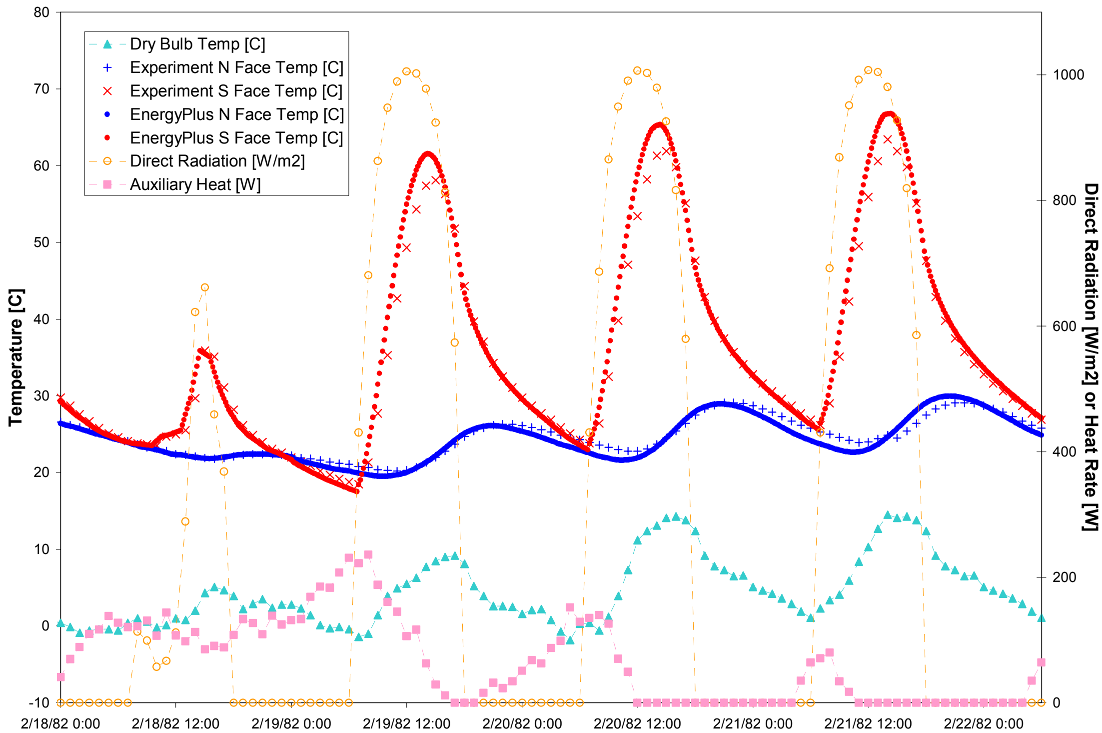

Figure 34. Painted Trombe wall cell surface temperature comparison, Feb. 18-22.

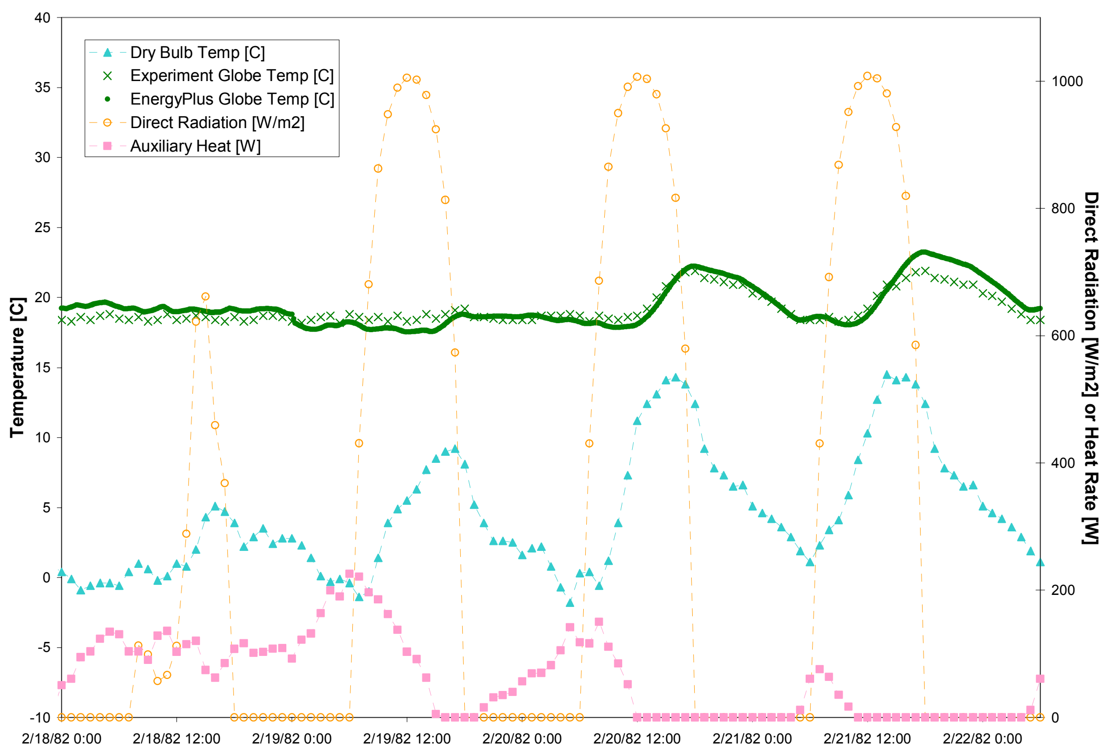

Figure 35. Selective surface Trombe wall cell globe temperature comparison, Feb. 18-22.

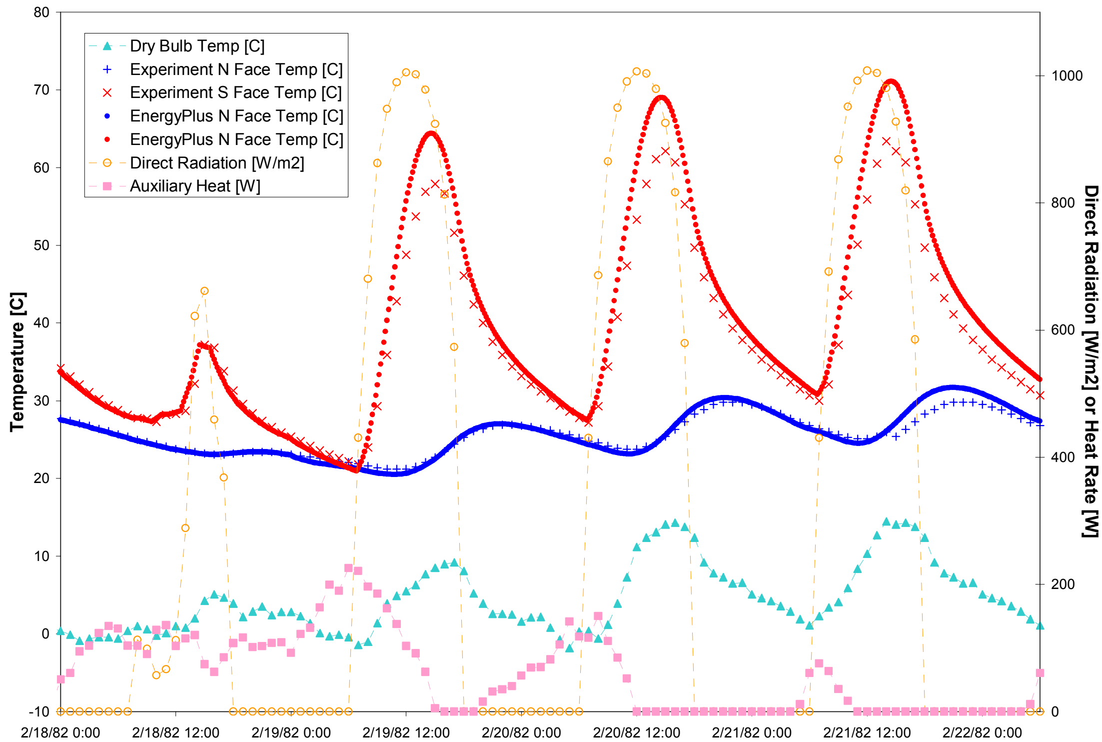

Figure 36. Selective surface Trombe wall cell surface temperature comparison, Feb. 18-22.

The surface temperature comparisons in Figures 34 and 36 show good agreement. While the shape matches very well for both north and south faces, the south face temperatures (in the Trombe air gap) are somewhat high, especially for the selective surface test cell. The north face temperatures (in the main zone), however, are arguably more important since they participate directly in the main zone heat balance. The north face temperatures show much better agreement for both Trombe walls.

3.5 SUMMARY

The most important part of the Trombe wall model validation is to verify that the resulting heat flux through the wall is correct. An accurate heat flux is critical for the designer to be able to determine how well a wall works for a given building design.

Since the three clear sky days of the validation are nearly steady-periodic, the surface temperatures on either side of the Trombe wall can be averaged over the period. Using the average temperature difference with k and L from the experiment, the average heat flux can be calculated.

$$\overline{q''} = \frac{k\Delta\overline{T}}{L}$$

The experimental and simulated average heat flux for both Trombe wall cells are presented here.

	Average Heat Flux (W/m²)			
Test Cell	*Experiment*	*EnergyPlus*	*Absolute Error*	*Percent Error*
Trombe wall, painted	48.7	54.9	6.2	12.8%
Trombe wall, selective surface	53.5	65.0	11.5	21.5%

Figure 37. Average heat flux comparison for Trombe wall test cells.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 THEORETICAL VALIDATION

The theoretical component of the Trombe wall model validation constituted a comparison of the Trombe zone convection coefficient correlation calculated by EnergyPlus with other accepted correlations and other simulation programs. The EnergyPlus correlation (ISO 15099) gave the highest Nusselt number values in the upper Rayleigh number range of any of the correlations. It is notable that there is a significant spread between many of the correlations. The ISO 15099 correlation is reportedly based on experiments over a wide range of values using a well-established experimental procedure (Wright 1989). The fact that it was selected by the International Standards Organization for convection in windows should also be some indication of its validity.

The question of the effect of surface roughness perhaps deserves some further research, although in the case of a selective surface, the roughness should be comparable to glass.

4.2 EXPERIMENTAL VALIDATION

The experimental component of the validation compared data from the Los Alamos test cells to simulated results from EnergyPlus. The overall comparison of the four test cells was quite successful showing good agreement in some regard for each test cell. The important criteria for validating the Trombe wall model were the wall surface temperatures and related average heat fluxes. The north face surface temperatures (in the main zone) agreed very well for both painted and selective surface Trombe walls. The south face surface temperatures (in the air gap) were slightly higher than expected. Comparison of experimental and simulated average heat flux showed better agreement for the painted Trombe wall than for the selective surface Trombe wall.

To reiterate an earlier point, experimental surface temperatures measure a local temperature at a thermocouple. Surface temperatures predicted by EnergyPlus represent an average value for the entire face. The uncertainty in comparing them may contribute to the differences between experiment and simulation.

The fact that better agreement was not achieved with the reference cell and direct gain cell, despite calibration, suggests that there are other sources of error. Some of the experimentally measured parameters with high sensitivity, such as the ventilation rate or the glass transmissivity, could be reexamined and perhaps calibrated.

Some doubts remain about the validity of the solar radiation data calculated by the selected models. Other solar models that were considered for estimating high altitude beam and diffuse radiation often gave inconsistent results. The direct gain and Trombe wall test cells are especially sensitive to the amount of solar radiation. Excessive solar radiation could be responsible for over-prediction of the EnergyPlus surface temperatures. Higher errors for the selective surface Trombe wall are consistent with this hypothesis.

As the next best thing to measured beam and diffuse components, an improved multi-array pyranometer analysis of the existing measurements merits further investigation. It may be the only way to accurately determine the solar radiation at the time of the experiment.

The nature of experimental test cells also introduces some error. The small size of the test cell zone may distort the standard heat transfer processes assumed for a normal size room, especially for interior convection. Two- and three-dimensional conductive heat transfer also becomes more significant at such a small size, contradicting the one-dimensional assumption.

4.3 SUMMARY

Buildings are complex, time-dependent systems with many variables. The present validation has shown that the EnergyPlus unvented Trombe wall model performs well compared to experimental data. Users should not hesitate to use the model for the simulation of passive solar buildings.

BIBLIOGRAPHY

Anderson, B.; Michal, C.; Temple, P.; and Lewis, D. 1980. *Passive Solar Design Handbook, Volume One: Passive Solar Design Concepts*, DOE/CS-0127/1. U. S. Department of Energy.

Andersson, B.; Bauman, F.; and Kammerud, R. 1980. "Verification of BLAST by Comparison with Direct Gain Test Cell Measurements", LBL-10619.

Baars, J.; Holt, D; and Stone, G. 1998. "Meteorological Monitoring at Los Alamos", LA-UR-98-2148. Los Alamos National Laboratory.

Balcomb, J. D.; McFarland, R. D.; and Hedstrom, J. C. 1977. "Simulation Analysis of Passive Solar Heated Buildings—Preliminary Results", *Solar Energy*, Vol. 19, pp. 277-282.

Balcomb, J. D.; McFarland, R. D.; and Moore, S. W. 1978. "Passive Testing At Los Alamos", *Proceedings of the 2nd National Passive Solar Conference, Philadelphia, PA, March 16-18, 1978*, Vol. 2.2.

Balcomb, J. D.; Hedstrom, J. C.; and Moore, S. W. 1979. "Performance Data Evaluation of the Balcomb Solar Home (SI Units)", *Proceedings of the 2nd Annual Solar Heating and Cooling Systems Operational Results, November 27-30, 1979, Colorado Springs, CO*. Los Alamos, NM: Los Alamos Scientific Laboratory.

Balcomb, J. D.; Barley, D.; McFarland, R.; Perry, J.; Wray, W.; and Noll, S. 1980a. *Passive Solar Design Handbook, Volume Two: Passive Solar Design Analysis*, DOE/CS-0127/2. U. S. Department of Energy.

Balcomb, J. D.; Hedstrom, J. C.; and Perry, J. E. 1980b. "Performance Evaluation of the Balcomb Solar House", *Proceedings of the International Colloquium on Passive Solar House Testing, Nice, France, December 11-12, 1980*. Los Alamos, NM: Los Alamos Scientific Laboratory.

Balcomb, J. D.; Hedstrom, J. C.; and Perry, J. E. 1981. "Performance Summary of the Balcomb Solar House", *Proceedings of the Annual Meeting, American Section of the International Solar Energy Society, Philadelphia, PA, May 27-30, 1981*. Newark, DE: American Section of the International Solar Energy Society.

Balcomb, J. D.; Jones, R. W.; McFarland, R. D.; and Wray, W. O. 1984. *Passive Solar Heating Analysis: A Design Manual*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Balcomb, J. D. 1992. "Introduction", *Passive Solar Buildings*, Balcomb, J. D. (ed.), pp. 1-37. Cambridge, MA: The MIT Press.

Balcomb, J. D. 2003. Private communication.

Barry, R. G. 1981. *Mountain Weather and Climat*e. New York: Methuen.

Bauman, F.; Andersson, B.; Carroll, W. L.; Kammerud, R.; and Friedman, N. E. 1983. "Verification of BLAST by Comparison With Measurements of a Solar-Dominated Test Cell and a Thermally Massive Building", *Journal of Solar Energy Engineering*, Vol. 105, pp. 207-216.

Casperson, R. L.; and Hocevar, C. J. 1979. "Experimental Investigation of the Trombe Wall", DOE/CS/34145-1. Energy Engineering Group, Inc. Golden, Colorado. U.S. Department of Energy.

Duffie, J. A.; and W. A. Beckman. 1991. *Solar Engineering of Thermal Processes, Second Edition*. New York, NY: John Wiley & Sons, Inc.

Duncan, I. P.; and Prowler, D. 1978. "Testing and Simulation of Passive Solar Systems", *Proceedings of the 2nd National Passive Solar Conference, Philadelphia, PA, March 16-18, 1978*, Vol. 2.2, pp. 581-587.

ElSherbiny, S. M.; Raithby, G. D.; and Hollands, K. G. T. 1982. "Heat Transfer by Natural Convection Across Vertical and Inclined Air Layers", *Journal of Heat Transfer*, Vol. 104, pp. 96-102.

EnergyPlus. 2003. "EnergyPlus Engineering Document: The Reference to EnergyPlus Calculations". U. S. Department of Energy.

ESP-r, 2001, "Data Model Summary: ESP-r Version 9 Series". Energy Systems Research Unit, University of Strathclyde, Scotland, UK.

Faiman, D.; Feuermann, D.; and Zemel, A. 1993. "Site-Independent Algorithm for Obtaining the Direct Beam Insolation from a Multipyranometer Instrument", *Solar Energy*, Vol. 50, No. 1, pp. 53-57.

Frey, D. J. 1992. "Performance Monitoring and Results", *Passive Solar Buildings*, J. D. Balcomb (ed.). Cambridge, MA: The MIT Press, 1992, pp. 399-483.

Goldstein, D. B. 1978. *Some Analytic Models of Passive Solar Building Performance: A Theoretical Approach to the Design of Energy-Conserving Buildings*, PhD dissertation, December 1978.

Hollands, K. G. T.; Unny, T. E.; Raithby, G. B.; and Konick, L. 1976. "Free Convection Heat Transfer Across Inclined Air Layers", *Journal of Heat Transfer*, Vol. 98, pp. 189-193.

ISO 15099. 2000. "Thermal Performance of Windows, Doors, and Shading Devices—Detailed Calculations". International Standards Organization, Draft, July 18, 2000.

James, L. T.; and Gross, W. A. 1991. "Heat Transfer by Convection and Thermal Radiation in a Small Scale Trombe Wall Simulation Enclosure", *1991 Solar World Congress*, Vol. 3, Part 1, pp. 2991-2996.

Jakob, M. 1949. *Heat Transfer, Volume 1*. New York: John Wiley & Sons, Inc.

Jones, R.W. (ed.); Balcomb, J. D.; Kosiewicz, C. E.; Lazarus, G. S.; McFarland, R. D.; and Wray, W. O. 1982. *Passive Solar Design Handbook, Volume Three: Passive Solar Design Analysis*, DOE/CS-0127/3. U. S. Department of Energy.

SERI/TR-0924-2. 1980. "Performance Data for Passive Systems: The Los Alamos Scientific Laboratory Test Rooms". Los Alamos Scientific Laboratory.

MacGregor, R. K.; and Emery, A. F. 1969. "Free Convection Through Vertical Plane Layers—Moderate and High Prandtl Number Fluids", *Journal of Heat Transfer*, pp. 391-403.

Marion, B. 1998. "Multi-Pyranometer Array Design and Performance Summary", *Proceedings of the 1998 American Solar Energy Society Annual Conference, Albuquerque, NM, June 14-17, 1998*.

McFarland, R. D. 1978. "PASOLE: A General Simulation Program for Passive Solar Energy", LA-7433-MS. Los Alamos National Laboratory.

McFarland, R. D. 1982. "Passive Test Cell Data for the Solar Laboratory Winter 1980-81", LA-9300-MS. Los Alamos National Laboratory.

McFarland, R. D.; Hedstrom, J. C.; Balcomb, J. D.; and Moore, S. W. 1982. "Los Alamos Passive Test Cell Results for the 1981-82 Winter", LA-9543-MS. Los Alamos National Laboratory.

Moore, J. E.; Schnurr, N. M.; Kerrisk, J. F.; and Hunn, B. D. 1981. "Thermal Storage Wall Model Development in DOE-2 Computer Program", *Proceedings of the 1981 Annual Meeting of the American Section of the International Solar Energy Society, Inc.*, Vol. 2, pp. 972-976.

Moore, F. 1982. "Passive Solar Test Modules", *Passive Solar Journal*, Vol. 1, No. 2, pp. 91-.

Moore, F. 1992. "Test Modules", *Passive Solar Buildings*, Balcomb, J. D. (ed.), pp. 293-329. Cambridge, MA: The MIT Press.

Morse, E. L. 1881. "Warming and Ventilating Apartments by Sun's Rays", U. S. Patent 246,626.

Mull, W.; and Reiher, H. 1930. *Gesundh.-Ing. Beihefte*, Reihe 1, No. 28.

NOAA. National Oceanic and Atmospheric Administration. As found in Greg Pelletier's Excel/VBA spreadsheet.

NREL. 2003. http://www.nrel.gov/buildings_thermal/passive_solar.html

Palmiter, L.; Wheeling, T.; and Corbett, B. 1978. "Performance of Passive Test Units in Butte, Montana", *Proceedings of the 2nd National Passive Solar Conference, Philadelphia, PA, March 16-18, 1978*, Vol. 2.2, pp. 591-594.

PASSYS. 1994. "The PASSYS Project: PASSYS Test Components Descriptions". European Commission. Directorate-General XII for Science, Research and Development.

Raithby, G. D.; Hollands, K. G. T.; and Unny, T. E.. 1977. "Analysis of Heat Transfer by Natural Convection Across Vertical Fluid Layers", *Journal of Heat Transfer*, Vol. 99, pp. 287-293.

Randall, K. R.; Mitchell, J. W.; and El-Wakil, M. M. 1979. "Natural Convection Heat Transfer Characteristics of Flat-Plate Enclosures", *Journal of Heat Transfer*, Vol. 101, pp. 120-125.

Strachan, P. 2000. "ESP-r: Summary of Validation Studies", Energy Systems Research Unit, University of Strathclyde, Scotland, UK.

SUNREL. 2000. *SUNREL Technical Reference Manual*, National Renewable Energy Laboratory.

TRNSYS. *TRNSYS Main Manual*, "Section 4.8.6, Type 36: Thermal Storage Wall".

Trombe, F.; Robert, J. F.; Cabanat, M.; and Sesolis, B. 1977. "Concrete Walls to Collect and Hold Heat", *Solar Age*, Vol. 2, No. 8, pp. 13-19.

Trombe, F. 1972. U. S. Patent 3,832,992.

U. S. Department of Energy. 2001. *Monthly Energy Review*, March 2001. Energy Information Administration, U. S. Department of Energy.

U. S. Standard Atmosphere. 1962. *U. S. Standard Atmosphere*. U. S. Committee on Extension to the Standard Atmosphere, Washington, D.C.

Walton, G. 1981. "Passive Solar Extension of the Building Loads Analysis and System Thermodynamics (BLAST) Program". Champaign, IL: Department of the Army, Construction Engineering Research Laboratory.

Warrington, R. O.; and T. A. Ameel. 1995. "Experimental Studies of Natural Convection in Partitioned Enclosures with a Trombe Wall Geometry", *Journal of Solar Energy Engineering*, Vol .117, pp. 16-21.

Wright, J. L.; and H. F. Sullivan. 1989. "Natural Convection in Sealed Glazing Units: A Review", *ASHRAE Transactions*, Vol. 95, Part 1, pp. 592-603.

Wright, J. L. 1996. "A Correlation to Quantify Convective Heat Transfer Between Vertical Window Glazings", *ASHRAE Transactions*, Vol. 102, Part 1, pp. 940-946.

Appendix A: Raw Data

Data Channels

	Cell 1
Ch 1	Trombe wall temperature, midheight, south surface [F]
Ch 3	Trombe wall temperature, midheight, north surface [F]
Ch 6	Trombe wall temperature, bottom, north surface [F]
Ch 8	Auxiliary heat (ammeter) [W]
Ch 9	Globe temperature [F]
	Cell 2
Ch 11	Trombe wall temperature, midheight, south surface [F]
Ch 16	Trombe wall temperature, midheight, north surface [F]
Ch 17	Trombe wall temperature, midheight, under foil on south surface [F]
Ch 18	Auxiliary heat (ammeter) [W]
Ch 19	Globe temperature [F]
	Cell 11
Ch 104	Floor block temperature, center, top surface [F]
Ch 107	Shielded air temperature [F]
Ch 108	Auxiliary heat (ammeter) [W]
Ch 109	Globe temperature [F]
	Cell 12
Ch 118	Auxiliary heat (ammeter) [W]
Ch 119	Globe temperature [F]
	Cell 13
Ch 128	Auxiliary heat (ammeter) [W]
Ch 129	Globe temperature [F]
	Cell 14
Ch 139	Globe temperature [F]
	Weather
Ch 141	Instantaneous insolation on 90 degree tilt (vertical) [Btu/h ft2]
Ch 146	Instantaneous insolation on 60 degree tilt [Btu/h ft2]
Ch 147	Instantaneous insolation on 36 degree tilt [Btu/h ft2]
Ch 150	Instantaneous outdoor dry bulb temperature [F]
Ch 152	Instantaneous insolation on 0 degree tilt (horizontal) [Btu/h ft2]
Ch 156	Instantaneous insolation on 45 degree tilt [Btu/h ft2]
Ch 161	Average insolation on 90 degree tilt (vertical) [Btu/h ft2]
Ch 166	Average insolation on 60 degree tilt [Btu/h ft2]
Ch 167	Average insolation on 36 degree tilt [Btu/h ft2]
Ch 169	Average relative humidity
Ch 170	Average outdoor dry bulb temperature [F]
Ch 172	Average insolation on 0 degree tilt (horizontal) [Btu/h ft2]
Ch 173	Average infrared on horizontal surface [Btu/h ft2]
Ch 176	Average insolation on 45 degree tilt [Btu/h ft2]
Ch 177	Average wind velocity [mph]
Ch 178	Average wind direction [degrees from north]
Ch 179	Average dew point temperature [F]

CHANNELS 1-107, 2/14/82-2/15/82

Date/Time	Ch 1	Ch 3	Ch 6	Ch 8	Ch 9	Ch 11	Ch 16	Ch 17	Ch 18	Ch 19	Ch 104	Ch 107
2/14/82 0:00	89.0	82.1	78.3	41.4	65.5	97.1	84.0	97.6	41.4	65.3	78.4	66.3
2/14/82 1:00	86.8	81.4	77.6	47.2	65.1	94.9	83.4	95.6	63.3	65.6	77.9	65.5
2/14/82 2:00	84.8	80.6	77.4	77.2	65.1	92.9	82.7	93.5	64.6	65.3	77.8	65.5
2/14/82 3:00	83.0	79.9	78.3	106.7	65.5	91.0	82.1	91.8	89.7	65.6	78.9	65.7
2/14/82 4:00	81.3	79.1	77.4	98.0	65.4	89.2	81.3	90.1	98.5	65.0	78.2	65.5
2/14/82 5:00	79.7	78.3	77.5	125.2	65.5	87.6	80.6	88.5	122.3	65.7	80.5	65.6
2/14/82 6:00	78.3	77.5	77.6	138.0	65.5	86.1	80.0	87.2	143.3	65.9	79.9	65.8
2/14/82 7:00	79.4	76.8	77.4	129.4	65.8	86.7	79.2	88.9	111.5	65.2	77.9	65.3
2/14/82 8:00	88.7	76.1	76.3	106.2	65.4	94.1	78.4	99.2	95.1	65.2	76.4	68.3
2/14/82 9:00	101.5	75.5	75.5	88.6	65.6	105.2	77.8	110.9	69.6	65.1	77.0	72.4
2/14/82 10:00	107.9	74.9	74.3	41.4	65.6	110.6	77.3	119.4	34.9	65.2	81.5	74.0
2/14/82 11:00	101.6	74.6	73.5	29.0	65.6	106.6	76.9	109.8	0.0	65.2	78.9	71.9
2/14/82 12:00	104.2	74.6	72.7	0.0	65.1	108.4	76.9	113.3	0.0	65.8	79.5	73.2
2/14/82 13:00	106.8	74.8	72.5	0.0	65.5	110.9	77.1	114.9	0.0	65.9	79.7	74.8
2/14/82 14:00	109.3	75.3	72.7	0.0	66.3	113.2	77.7	117.3	0.0	66.9	79.6	76.1
2/14/82 15:00	103.1	75.8	72.9	0.0	66.3	108.6	78.1	110.3	0.0	67.1	78.8	73.1
2/14/82 16:00	96.2	76.1	72.9	0.0	65.9	102.7	78.5	103.6	0.0	66.8	77.4	70.2
2/14/82 17:00	91.2	76.4	73.0	0.0	65.5	98.1	78.7	98.7	0.0	66.3	76.2	68.6
2/14/82 18:00	87.6	76.6	73.4	11.4	65.3	94.8	78.8	95.4	0.0	65.6	75.2	66.9
2/14/82 19:00	84.7	76.7	74.1	52.8	65.7	92.0	78.6	92.6	11.6	65.1	74.3	65.7
2/14/82 20:00	82.6	76.5	74.0	49.9	64.9	89.8	78.5	90.4	35.4	65.0	74.9	65.4
2/14/82 21:00	80.8	76.2	74.9	79.0	65.1	87.9	78.3	88.7	63.9	64.9	74.9	65.5
2/14/82 22:00	79.3	75.8	75.3	80.3	65.3	86.3	78.0	87.2	64.4	65.3	75.6	65.5
2/14/82 23:00	77.8	75.6	74.9	87.2	65.7	84.8	77.6	85.6	80.9	65.0	76.0	65.6
2/15/82 0:00	76.4	75.1	75.2	103.4	65.6	83.3	77.1	84.3	97.9	65.6	77.5	65.5
2/15/82 1:00	75.1	74.4	74.9	103.6	65.0	82.1	76.6	82.9	82.8	65.1	76.7	65.5
2/15/82 2:00	73.9	73.8	74.5	109.9	64.9	80.8	76.1	81.8	121.5	65.0	78.3	65.7
2/15/82 3:00	72.7	73.4	75.2	145.8	65.0	79.7	75.7	80.7	138.5	65.5	78.1	65.5
2/15/82 4:00	71.6	73.1	75.9	167.7	65.6	78.4	75.2	79.4	137.0	65.6	80.0	65.7
2/15/82 5:00	70.5	72.4	76.1	186.1	65.1	77.3	74.8	78.4	181.0	65.8	81.0	65.8
2/15/82 6:00	69.5	72.2	76.0	202.8	65.5	76.2	74.3	77.4	194.8	65.9	81.1	65.8
2/15/82 7:00	74.8	71.7	76.2	211.6	65.6	80.4	73.8	84.2	200.6	65.5	76.9	65.2
2/15/82 8:00	87.0	71.0	75.6	177.5	65.0	90.6	73.2	96.7	163.4	65.0	76.0	69.4
2/15/82 9:00	101.1	70.8	74.5	140.6	65.6	103.0	72.9	110.7	153.0	65.6	76.5	74.2
2/15/82 10:00	115.1	70.5	74.2	105.9	65.3	115.6	72.7	124.3	110.2	65.8	87.2	78.5
2/15/82 11:00	126.9	70.8	72.9	69.7	65.2	126.7	72.7	135.4	70.5	65.1	88.6	82.2
2/15/82 12:00	135.7	71.3	73.3	80.0	65.7	135.3	73.1	143.6	63.8	65.2	98.2	85.2
2/15/82 13:00	140.9	72.3	73.0	40.0	65.3	141.1	73.9	148.2	72.3	65.3	94.1	87.2
2/15/82 14:00	142.0	73.5	73.5	34.1	65.7	142.5	75.0	148.6	0.0	65.4	91.4	88.4
2/15/82 15:00	138.6	75.0	73.7	0.0	65.4	140.3	76.5	144.8	0.0	66.1	90.7	88.2
2/15/82 16:00	130.3	76.6	74.4	0.0	65.7	130.7	78.1	134.8	0.0	66.5	89.8	84.9
2/15/82 17:00	115.4	78.0	75.2	0.0	65.5	119.6	79.6	120.2	0.0	66.2	87.8	78.0
2/15/82 18:00	106.6	79.2	75.8	0.0	65.2	112.4	80.8	112.7	0.0	65.6	86.0	74.5
2/15/82 19:00	100.8	80.2	76.6	17.5	65.1	107.2	81.6	107.4	0.0	65.0	84.3	72.2
2/15/82 20:00	96.4	80.7	77.0	29.7	65.1	103.1	82.2	103.3	35.5	65.5	82.6	70.3
2/15/82 21:00	92.9	80.9	77.9	52.5	65.8	99.8	82.4	100.1	46.0	65.3	81.1	68.7
2/15/82 22:00	90.1	80.8	77.6	47.1	65.1	97.1	82.3	97.3	47.0	65.0	79.5	67.2
2/15/82 23:00	87.5	80.4	78.3	86.4	65.8	94.6	82.1	94.9	92.3	65.4	78.0	66.0

CHANNELS 108-152, 2/14/82-2/15/82

Date/Time	Ch 108	Ch 109	Ch 118	Ch 119	Ch 128	Ch 129	Ch 139	Ch 141	Ch 146	Ch 147	Ch 150	Ch 152
2/14/82 0:00	0.0	65.8		65.4	274.9	66.0	65.2				31.3	
2/14/82 1:00	45.4	65.2		65.1	270.2	65.1	65.5				30.0	
2/14/82 2:00	161.1	65.0		65.1	284.3	65.8	65.2				31.5	
2/14/82 3:00	255.2	65.2		65.1	286.0	64.6	65.1				28.2	
2/14/82 4:00	268.0	64.9		65.7	291.3	65.4	64.8				30.6	
2/14/82 5:00	374.9	65.1		65.0	282.7	64.8	64.8				27.8	
2/14/82 6:00	329.3	65.3		65.2	292.6	64.8	65.3	9.8	2.9	2.4	30.6	1.8
2/14/82 7:00	202.0	65.1		64.8	292.3	66.2	65.4	44.9	43.5	39.9	31.8	30.8
2/14/82 8:00	57.1	69.1		65.0	256.0	65.9	65.6	158.8	158.5	153.0	34.9	107.8
2/14/82 9:00	0.0	74.0		65.1	250.5	65.6	65.0	103.0	140.8	132.0	38.3	95.5
2/14/82 10:00	0.0	75.1		65.3	172.5	64.6	65.5	291.9	314.1	327.3	42.3	242.6
2/14/82 11:00	0.0	72.3		65.0	177.9	66.2	65.8	73.6	87.6	98.5	41.1	98.6
2/14/82 12:00	0.0	73.9		64.9	152.0	65.4	66.1	141.2	169.5	181.2	43.3	158.4
2/14/82 13:00	0.0	75.5		65.8	126.5	65.8	66.8	109.6	135.9	142.8	43.9	122.0
2/14/82 14:00	0.0	76.6		66.0	105.5	65.1	68.0	143.2	166.0	172.2	46.5	137.2
2/14/82 15:00	0.0	73.3		66.3	114.6	64.9	68.0	33.7	46.6	49.9	43.3	50.0
2/14/82 16:00	0.0	70.1		66.0	129.5	64.9	66.9	9.1	14.6	14.6	40.9	14.4
2/14/82 17:00	0.0	68.1		65.7	160.7	66.1	65.7		1.1		38.8	
2/14/82 18:00	0.0	66.5		65.2	163.4	65.4	65.0				35.8	
2/14/82 19:00	0.0	65.2		65.3	195.7	65.2	65.1				33.7	
2/14/82 20:00	119.4	65.3		65.6	216.7	65.0	65.2				32.3	
2/14/82 21:00	171.0	65.1		65.1	212.4	64.8	65.8				32.2	
2/14/82 22:00	232.3	65.2		65.4	221.0	65.8	65.4				32.1	
2/14/82 23:00	252.8	65.0		65.1	219.7	65.0	65.5				30.8	
2/15/82 0:00	326.7	64.9		65.3	229.7	64.9	65.4					
2/15/82 1:00	270.5	65.0		65.7	231.4	64.9	65.2					
2/15/82 2:00	357.1	65.1		65.3	229.7	65.6	65.6					
2/15/82 3:00	346.7	64.9		64.9	252.3	66.1	65.3					
2/15/82 4:00	434.2	65.3		65.3	253.9	65.7	64.9					
2/15/82 5:00	462.5	65.0		64.9	266.7	64.9	65.3					
2/15/82 6:00	469.7	65.1		65.1	293.9	65.6	65.0	-0.2				2.0
2/15/82 7:00	144.1	66.3		65.0	303.4	65.5	65.3	111.6				72.3
2/15/82 8:00	0.0	71.2		64.9	267.0	65.8	65.5	183.8				155.8
2/15/82 9:00	0.0	75.8		65.8	233.7	64.8	65.6	236.5				170.3
2/15/82 10:00	0.0	79.6		65.3	187.9	65.2	65.6	273.6				209.1
2/15/82 11:00	0.0	83.2		64.9	170.5	66.3	67.1	287.5				225.2
2/15/82 12:00	0.0	86.5		65.1	133.1	65.0	69.2	282.0				222.6
2/15/82 13:00	0.0	88.4		65.2	178.5	65.0	71.4	257.8				196.7
2/15/82 14:00	0.0	89.5		65.5	116.2	65.5	72.9	213.7				150.8
2/15/82 15:00	0.0	89.7		66.1	106.7	64.9	73.9	156.9				93.6
2/15/82 16:00	0.0	86.0		66.9	125.8	66.1	73.5	79.3				8.2
2/15/82 17:00	0.0	77.8		66.6	147.4	66.4	71.3	-3.9				-1.8
2/15/82 18:00	0.0	74.1		66.2	177.3	64.7	68.8	-2.0				-1.8
2/15/82 19:00	0.0	71.6		65.7	232.3	65.8	66.6					
2/15/82 20:00	0.0	69.7		65.3	223.7	65.3	65.4					
2/15/82 21:00	0.0	68.1		65.2	248.7	64.9	65.1					
2/15/82 22:00	0.0	66.7		65.5	271.2	64.6	65.0					
2/15/82 23:00	0.0	65.3		65.4	271.8	65.6	65.1					

CHANNELS 156-179, 2/14/82-2/15/82

Date/Time	Ch 156	Ch 161	Ch 166	Ch 167	Ch 169	Ch 170	Ch 172	Ch 173	Ch 176	Ch 177	Ch 178	Ch 179
2/14/82 0:00					40.2	31.1				1.1	144.3	9.7
2/14/82 1:00					41.0	30.9				0.8	144.9	9.9
2/14/82 2:00					40.8	30.8				1.5	137.1	9.8
2/14/82 3:00					44.6	29.0				0.7	135.3	10.0
2/14/82 4:00					43.4	29.6				1.0	206.8	10.0
2/14/82 5:00					45.9	28.1				0.9	256.9	9.9
2/14/82 6:00	1.7	0.0	1.5	0.7	44.3	29.0				1.1	152.6	10.0
2/14/82 7:00	48.5	19.4	20.6	18.7	43.5	31.0	14.2		22.3	0.6	254.5	11.3
2/14/82 8:00	190.9	95.8	97.6	93.2	45.8	33.7	66.8		117.7	0.7	328.6	15.0
2/14/82 9:00	144.4	177.9	184.4	180.6	47.1	36.3	124.0		218.0	0.8	285.3	18.0
2/14/82 10:00	359.2	165.1	183.2	192.1	47.8	40.4	152.6		210.8	1.6	299.1	22.1
2/14/82 11:00	95.4	96.3	117.7	129.4	44.4	42.0	121.3		130.8	1.9	297.4	21.8
2/14/82 12:00	179.0	94.3	116.4	129.4	42.8	42.3	123.1		126.8	1.0	345.0	21.2
2/14/82 13:00	138.4	124.5	149.7	159.0	42.7	43.2	138.2		155.6	1.0	302.3	22.0
2/14/82 14:00	166.9	133.3	159.1	161.1	40.2	45.6	127.5		152.2	3.6	356.9	22.8
2/14/82 15:00	47.0	64.9	82.5	84.9	36.9	44.5	75.2		80.0	5.0	345.1	19.8
2/14/82 16:00	14.4	17.4	24.7	25.6	37.5	42.4	26.1		24.4	1.5	311.8	18.3
2/14/82 17:00		0.0	4.5	3.2	41.1	40.0			3.2	0.9	371.9	18.2
2/14/82 18:00					42.6	37.9				1.0	305.9	17.2
2/14/82 19:00					44.0	34.6				1.8	300.9	14.9
2/14/82 20:00					42.9	32.9				0.7	359.4	12.7
2/14/82 21:00					41.9	32.5				0.6	258.8	11.4
2/14/82 22:00					42.6	32.8				0.6	281.6	12.3
2/14/82 23:00					44.5	30.9				0.6	210.2	11.7
2/15/82 0:00					37.7	34.5				9.5	200.9	11.2
2/15/82 1:00					43.8	35.7				11.0	212.7	15.6
2/15/82 2:00					53.8	33.9				1.2	180.9	18.9
2/15/82 3:00					58.2	31.5				0.8	190.9	18.4
2/15/82 4:00					61.2	29.2				1.3	364.0	17.5
2/15/82 5:00					65.0	27.1				0.6	391.8	16.9
2/15/82 6:00		0.0			64.9	26.2				0.6	427.9	16.0
2/15/82 7:00		68.6			62.4	26.9	40.7			0.6	201.0	15.8
2/15/82 8:00		156.8			65.4	31.0	113.4			2.1	233.5	20.7
2/15/82 9:00		210.4			66.9	35.0	160.8			2.5	224.6	25.0
2/15/82 10:00		254.9			76.9	38.9	190.3			3.2	286.9	31.9
2/15/82 11:00		282.9			69.0	41.0	219.0			4.3	333.3	31.6
2/15/82 12:00		285.4			68.5	42.6	225.5			4.6	312.4	32.5
2/15/82 13:00		271.4			62.3	43.6	211.0			4.2	344.5	31.6
2/15/82 14:00		237.3			62.3	44.1	175.1			3.6	320.0	32.0
2/15/82 15:00		187.1			62.1	45.0	123.9			2.5	322.2	32.8
2/15/82 16:00		119.4			61.6	44.7	59.7			4.5	257.3	32.3
2/15/82 17:00		22.4			62.1	40.0	5.4			4.8	263.2	28.0
2/15/82 18:00		0.0			61.1	34.8				1.2	327.9	22.8
2/15/82 19:00					59.9	31.5				1.6	335.2	19.2
2/15/82 20:00					56.2	30.5				1.4	337.8	16.8
2/15/82 21:00					55.3	29.9				0.6	356.2	15.5
2/15/82 22:00					57.4	29.0				0.6	399.4	15.5
2/15/82 23:00					54.4	28.9				1.9	450.9	14.5

Channels 1-107, 2/16/82-2/17/82

Date/Time	Ch 1	Ch 3	Ch 6	Ch 8	Ch 9	Ch 11	Ch 16	Ch 17	Ch 18	Ch 19	Ch 104	Ch 107
2/16/82 0:00	85.3	79.9	77.6	72.0	64.9	92.4	81.6	92.8	65.8	64.9	77.6	65.5
2/16/82 1:00	83.4	79.4	78.6	112.0	65.9	90.5	81.2	90.9	111.9	65.7	78.3	65.7
2/16/82 2:00	81.6	78.8	78.6	110.1	65.9	88.7	80.5	89.2	103.9	65.5	78.6	65.6
2/16/82 3:00	80.0	78.0	77.8	117.1	65.4	86.9	79.9	87.6	122.0	65.1	79.4	65.8
2/16/82 4:00	78.4	77.4	78.0	146.4	65.5	85.4	79.3	86.1	156.6	65.8	80.0	65.7
2/16/82 5:00	77.0	76.6	77.5	149.1	65.0	84.0	78.7	84.7	162.5	65.7	81.2	65.7
2/16/82 6:00	75.8	76.0	78.3	187.9	65.8	82.6	78.0	83.5	162.3	65.1	80.9	65.8
2/16/82 7:00	80.6	75.3	76.9	143.3	64.9	86.5	77.3	89.9	153.7	65.3	76.8	66.2
2/16/82 8:00	92.1	74.8	76.5	122.9	65.6	95.9	76.8	101.5	102.6	65.1	76.2	70.3
2/16/82 9:00	105.3	74.1	74.9	60.8	65.4	107.5	76.2	114.7	183.4	65.7	77.0	75.3
2/16/82 10:00	118.6	73.7	73.7	34.3	65.3	119.5	75.8	127.6	28.7	65.0	87.3	79.7
2/16/82 11:00	130.2	73.6	73.0	18.1	65.5	130.3	75.8	138.6	35.2	65.6	89.1	83.5
2/16/82 12:00	139.1	74.1	72.8	0.0	66.0	138.9	76.1	146.9	0.0	66.2	99.0	87.4
2/16/82 13:00	134.1	75.0	73.1	0.0	66.5	136.4	76.9	141.6	0.0	66.9	94.4	85.2
2/16/82 14:00	127.3	76.3	74.0	0.0	67.2	131.0	78.1	133.0	0.0	67.8	91.5	82.9
2/16/82 15:00	122.5	77.9	75.0	0.0	68.0	126.7	79.6	128.4	0.0	68.6	90.1	82.4
2/16/82 16:00	110.9	79.3	76.1	0.0	68.6	117.2	81.0	117.3	0.0	69.1	88.4	77.8
2/16/82 17:00	103.7	80.5	76.9	0.0	68.6	110.7	82.2	110.5	0.0	69.1	86.6	75.3
2/16/82 18:00	98.9	81.2	77.4	0.0	68.4	106.1	82.9	105.9	0.0	68.8	85.0	73.3
2/16/82 19:00	95.1	81.6	77.5	0.0	68.1	102.5	83.4	102.3	0.0	68.4	83.5	72.0
2/16/82 20:00	92.2	81.5	77.4	0.0	67.5	99.6	83.4	99.4	0.0	68.0	82.1	70.5
2/16/82 21:00	89.6	81.2	77.0	0.0	67.0	97.0	83.1	96.9	0.0	67.4	80.7	69.4
2/16/82 22:00	87.3	80.6	76.6	0.0	66.3	94.7	82.6	94.7	0.0	66.8	79.3	68.1
2/16/82 23:00	85.3	79.8	75.9	0.0	65.6	92.7	82.0	92.7	0.0	66.1	77.9	66.9
2/17/82 0:00	83.6	79.1	75.5	11.4	65.0	90.9	81.2	91.0	0.0	65.3	76.7	66.0
2/17/82 1:00	82.0	78.4	75.7	51.8	65.5	89.3	80.5	89.5	29.3	65.8	76.3	65.5
2/17/82 2:00	80.3	77.8	76.1	76.8	65.8	87.6	79.8	87.9	68.4	65.8	77.0	65.4
2/17/82 3:00	78.8	77.1	75.7	87.2	65.3	86.1	79.3	86.5	86.1	65.6	77.7	65.4
2/17/82 4:00	77.5	76.4	75.9	104.3	65.5	84.7	78.6	85.2	103.3	65.6	79.0	65.6
2/17/82 5:00	76.2	75.9	75.7	114.3	65.2	83.3	78.0	83.9	105.9	65.1	78.6	65.5
2/17/82 6:00	75.0	75.1	76.9	150.1	65.4	82.2	77.4	82.9	132.6	65.1	80.0	65.6
2/17/82 7:00	79.9	74.6	75.8	128.4	65.2	86.1	76.8	89.1	148.2	65.7	75.5	66.1
2/17/82 8:00	91.3	73.8	75.4	120.5	65.0	95.4	76.2	100.8	88.0	65.3	75.1	70.4
2/17/82 9:00	104.6	73.5	75.2	99.4	65.5	107.1	75.8	114.0	94.7	65.8	75.9	74.7
2/17/82 10:00	117.6	73.1	73.6	69.6	65.0	119.0	75.3	126.9	69.4	65.1	86.9	78.5
2/17/82 11:00	129.7	73.1	73.5	71.5	65.5	130.1	75.2	138.5	78.4	65.3	88.3	82.5
2/17/82 12:00	134.8	73.5	72.9	38.4	64.9	135.6	75.5	142.9	29.2	65.2	95.8	84.4
2/17/82 13:00	142.0	74.2	73.1	18.2	65.4	142.5	76.2	149.6	0.0	65.6	92.8	87.7
2/17/82 14:00	133.5	75.4	73.5	0.0	65.9	136.9	77.4	139.6	0.0	66.6	90.8	84.7
2/17/82 15:00	126.1	76.9	74.4	0.0	66.5	130.9	78.8	132.2	0.0	67.3	89.5	82.4
2/17/82 16:00	114.9	78.4	75.3	0.0	66.9	121.6	80.3	121.7	0.0	67.6	87.7	78.3
2/17/82 17:00	106.6	79.7	76.1	0.0	66.8	114.1	81.6	113.7	0.0	67.6	86.2	75.0
2/17/82 18:00	100.6	80.5	76.5	0.0	66.4	108.6	82.3	108.1	0.0	66.7	84.4	72.5
2/17/82 19:00	96.3	80.9	76.7	0.0	66.0	104.4	82.7	104.1	0.0	66.0	82.9	70.7
2/17/82 20:00	93.0	80.9	76.7	0.0	65.8	101.1	82.9	100.8	0.0	66.1	81.5	69.4
2/17/82 21:00	90.1	80.7	76.4	0.0	65.3	98.2	82.6	98.0	0.0	65.4	80.0	68.0
2/17/82 22:00	87.8	80.3	77.0	29.1	65.9	95.9	82.2	95.8	5.9	65.1	78.5	67.2
2/17/82 23:00	85.6	79.8	76.7	40.7	65.5	93.6	81.8	93.6	50.9	65.1	77.3	65.7

CHANNELS 108-152, 2/16/82-2/17/82

Date/Time	Ch 108	Ch 109	Ch 118	Ch 119	Ch 128	Ch 129	Ch 139	Ch 141	Ch 146	Ch 147	Ch 150	Ch 152
2/16/82 0:00	73.3	65.1		65.4	269.8	65.3	64.9					
2/16/82 1:00	187.9	65.3		65.5	289.3	65.9	65.4					
2/16/82 2:00	244.0	65.1		65.0	293.1	66.1	65.3					
2/16/82 3:00	319.2	65.3		65.4	292.5	65.7	65.1					
2/16/82 4:00	349.5	65.3		65.0	294.9	65.7	65.0					
2/16/82 5:00	409.8	65.0		65.2	305.3	64.4	65.4					
2/16/82 6:00	377.5	65.2		65.1	313.5	65.7	64.8	-13.5				2.8
2/16/82 7:00	61.8	66.8		65.3	285.8	65.9	65.4	107.5				88.1
2/16/82 8:00	0.0	72.0		64.9	245.0	65.1	65.0	164.1				122.0
2/16/82 9:00	0.0	76.6		66.3	300.8	65.4	65.2	221.9				169.3
2/16/82 10:00	0.0	80.5		65.2	159.7	65.5	66.3	256.7				207.2
2/16/82 11:00	0.0	84.5		65.4	112.4	65.1	68.6	270.8				224.2
2/16/82 12:00	0.0	88.4		66.0	96.3	64.9	71.5	271.5				227.3
2/16/82 13:00	0.0	85.9		67.0	80.1	65.0	73.3	138.0				122.5
2/16/82 14:00	0.0	83.6		67.7	70.8	65.0	73.6	55.1				79.7
2/16/82 15:00	0.0	83.0		68.5	92.7	65.3	73.3	56.5				51.4
2/16/82 16:00	0.0	77.5		69.2	72.8	65.7	72.4	5.1				13.0
2/16/82 17:00	0.0	74.8		69.3	104.0	65.2	70.6					
2/16/82 18:00	0.0	72.9		69.1	135.4	66.2	69.0					
2/16/82 19:00	0.0	71.5		68.8	149.9	65.6	67.6					
2/16/82 20:00	0.0	70.1		68.4	163.2	65.0	66.4					
2/16/82 21:00	0.0	69.0		67.8	192.0	65.7	65.2					
2/16/82 22:00	0.0	67.7		67.1	193.8	65.0	65.2					
2/16/82 23:00	0.0	66.5		66.3	214.7	65.7	65.1					
2/17/82 0:00	0.0	65.6		65.6	223.2	65.4	65.2					
2/17/82 1:00	58.6	65.0		65.5	219.2	65.2	65.0					
2/17/82 2:00	189.0	64.9		65.6	253.9	66.4	65.1					
2/17/82 3:00	250.5	64.9		65.2	247.5	66.1	65.4					
2/17/82 4:00	292.4	65.1		65.2	249.0	65.8	65.4					
2/17/82 5:00	301.5	64.9		65.0	250.0	65.3	65.6					
2/17/82 6:00	361.7	65.0		64.9	276.4	65.4	65.1					
2/17/82 7:00	37.4	66.8		65.7	252.2	65.3	65.4	112.5				87.9
2/17/82 8:00	0.0	72.0		64.9	255.6	65.9	65.7	170.9				123.9
2/17/82 9:00	0.0	76.4		65.1	230.7	65.2	65.3	223.2				177.2
2/17/82 10:00	0.0	79.3		65.1	201.0	65.1	65.6	257.2				215.5
2/17/82 11:00	0.0	83.5		65.4	179.2	66.1	67.6	284.9				242.2
2/17/82 12:00	0.0	85.7		65.3	146.7	65.8	69.8	255.6				230.1
2/17/82 13:00	0.0	89.0		65.6	132.5	65.9	71.8	256.9				208.6
2/17/82 14:00	0.0	85.3		66.6	100.8	65.8	73.9	87.8				100.4
2/17/82 15:00	0.0	82.9		67.5	94.2	65.5	73.1	51.4				50.3
2/17/82 16:00	0.0	77.9		67.8	110.1	65.4	71.9	13.8				15.7
2/17/82 17:00	0.0	74.5		67.9	147.8	65.2	70.2	-1.8				-1.1
2/17/82 18:00	0.0	72.0		67.6	174.7	66.1	67.9					
2/17/82 19:00	0.0	70.2		67.3	194.3	65.2	66.4					
2/17/82 20:00	0.0	69.0		67.1	218.8	65.6	65.3					
2/17/82 21:00	0.0	67.6		66.4	219.1	65.6	65.2					
2/17/82 22:00	0.0	66.6		65.9	229.9	65.0	65.3					
2/17/82 23:00	0.0	65.3		65.3	244.7	66.0	65.5					

CHANNELS 156-179, 2/16/82-2/17/82

Date/Time	Ch 156	Ch 161	Ch 166	Ch 167	Ch 169	Ch 170	Ch 172	Ch 173	Ch 176	Ch 177	Ch 178	Ch 179
2/16/82 0:00					52.4	29.5				0.6	238.5	14.2
2/16/82 1:00					55.0	28.8				0.6	196.2	14.6
2/16/82 2:00					58.5	27.8				0.6	333.2	15.1
2/16/82 3:00					60.6	27.0				0.6	321.3	15.1
2/16/82 4:00					63.8	26.3				0.6	210.5	15.6
2/16/82 5:00					64.2	25.9				0.6	102.8	15.4
2/16/82 6:00		0.0			61.1	26.3				0.6	106.4	14.7
2/16/82 7:00		59.3			57.2	29.8	46.1			0.6	139.2	16.4
2/16/82 8:00		137.7			62.3	33.6	112.7			1.1	347.4	22.0
2/16/82 9:00		198.4			60.4	39.0	145.2			4.1	366.3	26.4
2/16/82 10:00		240.8			63.3	42.7	189.7			3.1	353.2	31.1
2/16/82 11:00		265.3			61.8	45.4	217.7			3.1	354.8	33.1
2/16/82 12:00		272.2			58.7	47.7	227.0			4.4	389.3	33.9
2/16/82 13:00		198.6			52.9	48.3	179.2			6.1	373.2	31.9
2/16/82 14:00		120.8			51.1	48.8	128.9			3.6	329.1	31.5
2/16/82 15:00		85.8			52.6	48.7	83.8			2.3	308.4	32.2
2/16/82 16:00		19.3			51.8	47.6	31.5			2.4	344.1	30.7
2/16/82 17:00					51.4	44.6				3.5	354.9	27.8
2/16/82 18:00					54.3	41.7				2.3	269.0	26.3
2/16/82 19:00					57.8	38.6				1.0	303.1	25.0
2/16/82 20:00					60.3	36.8				1.3	367.3	24.3
2/16/82 21:00					58.4	35.6				1.7	346.8	22.4
2/16/82 22:00					55.9	34.6				1.8	315.2	20.2
2/16/82 23:00					56.2	33.7				1.7	354.4	19.7
2/17/82 0:00					58.5	33.1				1.0	294.2	20.1
2/17/82 1:00					61.7	32.3				1.3	70.1	20.6
2/17/82 2:00					63.2	31.4				2.0	169.7	20.3
2/17/82 3:00					64.8	30.9				0.6	257.7	20.4
2/17/82 4:00					64.8	31.5				0.7	114.5	21.0
2/17/82 5:00					66.5	31.7				0.6	106.2	21.8
2/17/82 6:00					71.6	30.0				1.2	142.4	21.9
2/17/82 7:00		70.3			66.8	31.8	44.0			0.6	296.7	22.0
2/17/82 8:00		136.9			71.1	34.9	109.2			1.8	275.4	26.5
2/17/82 9:00		196.7			73.6	38.0	149.7			8.1	237.8	30.3
2/17/82 10:00		242.5			74.1	39.4	197.5			8.4	236.7	31.8
2/17/82 11:00		271.0			70.9	41.3	228.3			7.8	221.7	32.6
2/17/82 12:00		250.8			64.5	43.8	226.3			6.4	229.4	32.6
2/17/82 13:00		258.7			56.7	45.8	219.9			4.0	264.4	31.3
2/17/82 14:00		176.1			53.0	46.8	155.4			4.4	317.3	30.5
2/17/82 15:00		99.2			45.6	45.8	93.7			5.3	353.7	26.0
2/17/82 16:00		32.4			46.8	43.4	32.2			4.4	373.2	24.4
2/17/82 17:00		6.0			49.7	40.8	6.3			2.2	391.2	23.4
2/17/82 18:00					50.3	38.2				3.8	445.8	21.3
2/17/82 19:00					50.6	36.0				3.8	474.4	19.4
2/17/82 20:00					49.9	35.3				2.1	198.1	18.4
2/17/82 21:00					51.5	34.1				2.7	189.4	18.0
2/17/82 22:00					49.5	33.4				0.6	121.4	16.1
2/17/82 23:00					50.1	32.7				1.0	107.4	16.0

CHANNELS 1-107, 2/18/82-2/19/82

Date/Time	Ch 1	Ch 3	Ch 6	Ch 8	Ch 9	Ch 11	Ch 16	Ch 17	Ch 18	Ch 19	Ch 104	Ch 107
2/18/82 0:00	83.6	79.2	76.9	69.4	65.6	91.6	81.3	91.6	60.8	65.0	77.6	65.5
2/18/82 1:00	81.7	78.6	76.9	88.7	65.4	89.8	80.8	89.8	94.7	65.5	77.5	65.5
2/18/82 2:00	80.0	77.9	76.8	109.4	65.2	88.0	80.2	88.2	103.6	65.2	78.4	65.5
2/18/82 3:00	78.5	77.2	76.7	116.8	65.2	86.4	79.6	86.7	123.2	65.6	80.0	65.6
2/18/82 4:00	77.2	76.6	77.1	138.1	65.5	84.9	79.0	85.4	134.6	65.9	79.3	65.6
2/18/82 5:00	76.2	75.9	76.6	127.2	65.2	83.8	78.3	84.3	130.7	65.3	78.8	65.7
2/18/82 6:00	75.3	75.3	76.0	120.4	65.1	82.8	77.7	83.4	103.5	65.1	79.1	65.6
2/18/82 7:00	74.8	74.6	75.7	121.7	65.3	82.1	77.0	83.3	103.5	65.4	78.5	65.7
2/18/82 8:00	74.7	73.9	76.2	131.0	65.4	81.8	76.4	82.7	90.2	64.9	77.9	65.6
2/18/82 9:00	74.3	73.5	74.8	107.0	65.1	81.2	75.9	82.4	128.5	65.2	77.6	65.2
2/18/82 10:00	76.5	73.1	75.6	143.5	65.9	82.7	75.4	84.8	135.9	65.9	76.0	65.5
2/18/82 11:00	77.0	72.4	75.0	107.2	65.2	82.9	74.9	85.0	103.0	65.2	75.4	65.4
2/18/82 12:00	77.9	72.1	73.7	97.5	65.0	83.6	74.4	86.0	114.9	65.3	74.4	65.3
2/18/82 13:00	85.5	71.8	73.6	112.8	65.3	89.9	74.1	93.5	120.2	65.6	75.0	67.4
2/18/82 14:00	96.6	71.5	72.9	84.9	64.9	98.9	73.7	105.0	74.6	65.4	75.0	71.3
2/18/82 15:00	95.2	71.2	72.9	90.4	65.0	98.3	73.6	101.3	62.3	65.1	74.5	70.8
2/18/82 16:00	88.0	71.4	72.8	88.1	65.0	92.8	73.5	94.1	85.3	65.0	73.7	67.6
2/18/82 17:00	82.7	71.8	73.4	108.3	65.3	88.4	73.7	89.1	107.9	65.5	74.1	65.7
2/18/82 18:00	79.2	72.1	74.1	133.1	65.4	85.3	73.9	85.9	116.9	65.0	75.6	65.6
2/18/82 19:00	76.9	72.3	74.6	127.0	65.6	83.1	74.1	83.8	101.3	65.2	75.1	65.7
2/18/82 20:00	75.2	72.3	74.3	109.0	65.1	81.4	74.2	82.1	102.8	65.7	76.1	65.5
2/18/82 21:00	73.6	72.3	74.7	138.6	65.3	79.9	74.1	80.6	108.3	65.6	75.6	65.4
2/18/82 22:00	72.6	72.1	74.7	124.6	65.0	78.6	73.9	79.4	109.2	65.5	76.7	65.7
2/18/82 23:00	71.6	71.9	74.5	131.3	65.2	77.7	73.6	78.4	92.5	65.0	76.0	65.5
2/19/82 0:00	70.6	71.5	74.3	133.3	65.0	76.7	73.3	77.4	122.0	64.8	77.8	65.8
2/19/82 1:00	69.6	71.3	75.3	168.6	65.8	75.6	73.0	76.4	131.9	65.1	78.6	65.7
2/19/82 2:00	68.4	70.8	75.9	185.1	65.4	74.5	72.6	75.3	163.7	65.4	78.9	65.7
2/19/82 3:00	67.5	70.5	74.9	183.1	64.8	73.6	72.4	74.4	199.6	65.6	79.7	65.5
2/19/82 4:00	66.6	70.2	75.3	207.4	65.1	72.7	72.0	73.6	189.9	64.8	81.2	65.8
2/19/82 5:00	65.9	70.0	76.1	230.7	65.8	71.9	71.7	72.8	225.6	65.9	81.5	65.6
2/19/82 6:00	65.3	69.5	75.5	222.2	65.1	71.3	71.4	72.2	221.2	65.5	81.9	65.7
2/19/82 7:00	70.3	69.2	75.9	235.7	65.6	75.2	70.9	78.4	196.6	65.1	77.3	65.0
2/19/82 8:00	81.9	68.8	74.9	187.7	65.4	84.8	70.6	90.1	185.4	65.5	76.3	69.0
2/19/82 9:00	95.6	68.5	73.8	160.4	65.2	96.7	70.2	103.6	162.3	64.9	76.9	73.8
2/19/82 10:00	108.8	68.3	74.1	145.0	65.2	109.0	70.2	116.6	138.0	65.6	87.6	77.3
2/19/82 11:00	120.7	68.6	72.8	106.0	65.0	119.9	70.2	127.8	103.4	64.9	96.1	81.1
2/19/82 12:00	129.7	69.3	73.8	116.3	65.9	128.7	70.7	136.1	91.4	65.2	102.5	85.1
2/19/82 13:00	135.3	70.3	73.3	62.6	65.7	134.4	71.7	141.0	62.6	65.8	96.4	87.6
2/19/82 14:00	136.6	71.6	73.0	29.2	65.2	136.2	72.8	141.4	5.6	65.3	93.3	88.8
2/19/82 15:00	133.4	73.1	73.4	12.0	65.3	134.0	74.3	137.3	0.0	65.9	92.2	88.6
2/19/82 16:00	125.2	74.6	73.9	0.0	65.6	124.8	75.9	127.5	0.0	66.4	91.2	85.4
2/19/82 17:00	111.8	76.4	74.9	0.0	66.0	114.9	77.6	115.0	0.0	66.5	89.5	79.2
2/19/82 18:00	103.5	77.7	75.6	0.0	65.4	108.3	78.9	108.0	0.0	65.5	87.5	75.6
2/19/82 19:00	98.7	78.4	76.6	15.9	65.4	104.0	79.6	103.6	15.8	65.4	85.9	73.6
2/19/82 20:00	93.8	79.1	77.6	31.7	65.4	99.6	80.3	99.2	31.6	65.3	84.2	71.6
2/19/82 21:00	90.5	79.4	77.0	23.2	65.4	96.6	80.5	96.2	34.9	65.1	82.6	70.1
2/19/82 22:00	87.9	79.4	77.4	34.3	65.4	94.0	80.5	93.7	39.9	65.2	81.1	68.9
2/19/82 23:00	85.6	79.0	77.1	51.1	65.4	91.7	80.3	91.5	56.7	65.1	79.5	67.2

CHANNELS 108-152, 2/18/82-2/19/82

Date/Time	Ch 108	Ch 109	Ch 118	Ch 119	Ch 128	Ch 129	Ch 139	Ch 141	Ch 146	Ch 147	Ch 150	Ch 152
2/18/82 0:00	99.6	65.1		65.4	258.6	65.8	65.6					
2/18/82 1:00	198.0	65.0		65.6	259.3	65.8	65.1					
2/18/82 2:00	293.0	64.9		65.1	277.4	65.9	65.3					
2/18/82 3:00	332.5	65.1		65.1	265.6	64.5	65.1					
2/18/82 4:00	303.4	65.1		65.3	279.4	65.8	64.9					
2/18/82 5:00	298.1	65.2		65.4	262.6	64.9	65.4					
2/18/82 6:00	291.0	65.1		65.2	259.0	65.4	65.6					
2/18/82 7:00	252.8	65.3		64.9	242.4	65.7	65.5	28.9				36.1
2/18/82 8:00	205.0	65.2		65.8	221.2	64.7	65.1	1.7				14.4
2/18/82 9:00	248.7	64.9		64.9	231.7	64.6	65.2	10.3				14.2
2/18/82 10:00	128.3	65.5		65.3	236.8	64.9	65.0	41.8				28.1
2/18/82 11:00	86.3	65.3		65.4	208.7	65.4	65.1	36.1				48.1
2/18/82 12:00	43.2	65.2		65.1	205.1	65.2	65.0	45.8				80.3
2/18/82 13:00	0.0	68.0		65.1	197.5	65.1	64.9	93.4				122.2
2/18/82 14:00	0.0	72.3		65.1	185.0	66.1	65.1	192.3				161.9
2/18/82 15:00	0.0	71.7		65.3	167.6	65.5	65.1	67.7				54.8
2/18/82 16:00	0.0	67.4		65.3	154.8	65.3	65.0	11.9				19.0
2/18/82 17:00	49.7	65.3		65.4	184.0	65.7	65.0					
2/18/82 18:00	226.7	65.2		65.4	199.3	65.2	65.8					
2/18/82 19:00	221.6	65.2		65.1	205.9	65.0	64.9					
2/18/82 20:00	262.8	65.1		64.9	204.3	65.6	65.4					
2/18/82 21:00	280.7	64.9		65.6	204.1	65.4	65.3					
2/18/82 22:00	309.2	65.1		65.9	209.4	65.8	65.5					
2/18/82 23:00	282.1	64.9		65.0	214.6	65.0	65.7					
2/19/82 0:00	341.4	65.4	123.2	65.1	204.1	64.6	65.3				35.9	
2/19/82 1:00	359.4	65.1	151.2	65.2	226.0	65.6	65.5				32.9	
2/19/82 2:00	404.7	65.2	173.9	65.0	253.4	65.6	65.5				31.8	
2/19/82 3:00	454.4	64.9	189.1	65.6	250.7	65.2	65.6				31.7	
2/19/82 4:00	462.6	65.1	182.0	65.0	256.9	65.7	65.4				31.5	
2/19/82 5:00	453.3	64.9	201.2	65.1	272.9	65.7	64.9				30.0	
2/19/82 6:00	463.6	65.1	233.1	65.7	262.6	64.7	65.0	10.5			28.8	2.8
2/19/82 7:00	118.2	65.9	212.9	65.3	284.8	65.9	65.3	115.9			32.3	56.1
2/19/82 8:00	0.0	70.7	315.8	66.5	258.7	66.0	65.0	142.3			36.2	120.3
2/19/82 9:00	0.0	75.7	73.1	65.2	218.4	65.0	65.4	225.0			41.2	174.6
2/19/82 10:00	0.0	78.9	57.6	65.4	190.0	65.9	65.4	255.2			41.2	214.6
2/19/82 11:00	0.0	82.6	52.0	65.6	157.8	64.8	66.4	264.5			41.8	232.6
2/19/82 12:00	0.0	86.4	6.2	65.3	151.5	65.5	68.4	263.7			44.4	228.6
2/19/82 13:00	0.0	88.8	0.0	66.0	125.2	65.6	70.7	239.5			45.9	202.2
2/19/82 14:00	0.0	90.1	0.0	67.3	98.6	65.7	72.8	200.4			49.5	157.0
2/19/82 15:00	0.0	90.3	0.0	68.1	99.7	65.7	73.6	146.5			49.9	100.2
2/19/82 16:00	0.0	86.5	0.0	68.8	80.2	65.7	73.5	72.4			48.6	18.5
2/19/82 17:00	0.0	79.0	0.0	68.9	99.6	65.9	72.2	-3.3			44.7	-2.6
2/19/82 18:00	0.0	75.2	0.0	68.6	142.3	65.8	69.5				39.2	
2/19/82 19:00	4.8	73.2	4.9	67.9	167.2	65.6	67.7				38.3	
2/19/82 20:00	9.5	71.1	8.7	67.2	192.1	65.4	65.8				37.3	
2/19/82 21:00	0.0	69.6	0.0	66.3	200.7	65.3	65.3				34.9	
2/19/82 22:00	0.0	68.4	0.0	65.8	215.3	64.8	65.3				35.7	
2/19/82 23:00	0.0	66.8	0.0	65.0	225.8	65.7	65.4				34.8	

CHANNELS 156-179, 2/18/82-2/19/82

Date/Time	Ch 156	Ch 161	Ch 166	Ch 167	Ch 169	Ch 170	Ch 172	Ch 173	Ch 176	Ch 177	Ch 178	Ch 179
2/18/82 0:00					50.0	31.8				0.7	104.7	15.2
2/18/82 1:00					51.0	30.4				0.7	82.6	14.4
2/18/82 2:00					48.3	31.0				4.1	462.2	13.8
2/18/82 3:00					47.7	31.2				2.7	455.2	13.6
2/18/82 4:00					48.1	31.2				1.3	470.4	13.8
2/18/82 5:00					49.1	31.0				1.5	175.4	14.1
2/18/82 6:00					48.7	32.7				1.2	197.8	15.4
2/18/82 7:00		0.0			49.3	33.8				4.0	182.3	16.8
2/18/82 8:00		7.3			52.3	33.0	23.9			2.6	360.9	17.5
2/18/82 9:00		0.0			58.4	31.6	13.8			1.3	317.0	18.7
2/18/82 10:00		19.0			53.7	32.1	15.8			0.6	172.1	16.9
2/18/82 11:00		23.6			54.9	33.8	25.1			0.8	169.8	19.0
2/18/82 12:00		28.0			60.1	33.5	47.9			0.6	178.4	20.9
2/18/82 13:00		88.2			61.4	35.6	125.9			3.0	160.1	23.6
2/18/82 14:00		147.8			70.1	39.7	139.6			2.2	189.1	30.7
2/18/82 15:00		87.3			78.9	41.2	82.7			1.8	194.0	35.2
2/18/82 16:00		29.0			81.2	40.4	33.6			1.2	136.7	35.1
2/18/82 17:00					77.4	39.1	8.3			2.3	112.2	32.7
2/18/82 18:00					76.1	36.0				5.1	382.3	29.2
2/18/82 19:00					67.9	37.2				5.9	413.8	27.6
2/18/82 20:00					62.7	38.3				6.5	380.6	26.7
2/18/82 21:00					63.4	36.4				7.3	395.7	25.2
2/18/82 22:00					62.4	37.1				3.7	382.5	25.5
2/18/82 23:00					63.4	37.1				3.4	382.6	25.8
2/19/82 0:00					61.1	36.2		114.6		4.3	391.4	23.9
2/19/82 1:00					63.7	34.5		124.8		4.0	393.7	23.5
2/19/82 2:00					65.5	32.2		122.5		4.4	419.6	21.9
2/19/82 3:00					66.4	31.4		121.1		4.2	465.2	21.5
2/19/82 4:00					64.3	31.9		120.8		3.8	472.4	21.2
2/19/82 5:00					65.5	31.3		120.7		4.0	476.6	21.1
2/19/82 6:00		0.0	1.9	0.1	69.0	29.4		119.4	-0.2	2.5	352.1	20.5
2/19/82 7:00		53.7	57.3	45.5	71.0	30.2	27.2	119.3	72.9	0.6	190.6	21.9
2/19/82 8:00		128.9	142.4	131.8	72.1	34.6	88.7	132.2	182.0	0.6	290.7	26.5
2/19/82 9:00		190.0	214.6	211.8	77.3	39.1	148.3	145.2	263.7	2.1	293.0	32.5
2/19/82 10:00		234.5	269.5	276.5	74.6	40.9	195.4	150.3	320.2	4.8	317.1	33.5
2/19/82 11:00		262.9	305.8	318.5	73.9	41.9	224.7	153.2	348.3	2.9	290.0	34.2
2/19/82 12:00		268.3	319.6	331.2	68.8	43.4	232.2	157.6	344.4	3.0	271.5	33.8
2/19/82 13:00		252.8	311.3	315.0	63.8	45.8	217.2	161.8	310.2	2.2	277.8	34.3
2/19/82 14:00		220.8	276.8	271.3	62.0	47.3	180.9	163.8	250.4	3.0	251.3	35.0
2/19/82 15:00		173.7	220.2	205.8	59.8	48.2	129.6	164.5	174.6	2.6	288.4	34.9
2/19/82 16:00		111.8	143.8	123.3	55.5	48.6	64.2	162.2	90.0	1.9	316.1	33.4
2/19/82 17:00		25.1	41.1	27.3	52.9	46.5	8.9	151.9	13.3	1.1	336.0	30.2
2/19/82 18:00			1.2	-1.6	57.3	41.3		139.3	-1.9	3.4	450.9	27.3
2/19/82 19:00					54.4	39.0		133.8		3.9	364.4	23.7
2/19/82 20:00					51.4	36.7		128.2		4.3	277.8	20.1
2/19/82 21:00					49.7	36.6		128.3		2.3	140.1	19.6
2/19/82 22:00					50.3	36.5		125.2		1.3	150.5	19.8
2/19/82 23:00					55.5	34.8		122.2		0.6	403.7	20.5

CHANNELS 1-107, 2/20/82-2/21/82

Date/Time	Ch 1	Ch 3	Ch 6	Ch 8	Ch 9	Ch 11	Ch 16	Ch 17	Ch 18	Ch 19	Ch 104	Ch 107
2/20/82 0:00	83.7	78.7	77.2	67.9	65.6	89.8	79.9	89.7	69.1	65.1	78.1	66.4
2/20/82 1:00	81.9	78.1	76.8	62.9	65.3	88.1	79.5	88.1	69.9	65.7	77.8	65.6
2/20/82 2:00	80.4	77.6	77.1	87.3	65.7	86.5	79.1	86.5	82.2	65.6	78.0	65.4
2/20/82 3:00	78.7	76.9	76.6	98.5	65.1	85.0	78.5	85.0	105.4	65.6	77.9	65.1
2/20/82 4:00	77.1	76.1	77.9	151.8	65.4	83.4	78.0	83.6	141.9	65.8	79.6	65.4
2/20/82 5:00	75.8	75.7	77.3	129.1	65.7	82.1	77.4	82.4	118.2	65.6	79.3	65.6
2/20/82 6:00	74.8	75.1	77.1	135.2	65.6	81.0	76.7	81.5	116.4	65.0	80.6	65.8
2/20/82 7:00	79.6	74.5	76.3	139.6	65.1	84.8	76.2	87.6	150.5	65.6	76.7	65.9
2/20/82 8:00	90.5	74.0	76.1	125.8	65.6	93.9	75.6	98.8	111.0	65.3	76.1	70.2
2/20/82 9:00	103.7	73.4	74.4	70.1	64.9	105.4	75.1	111.9	84.8	65.2	77.1	75.1
2/20/82 10:00	116.8	73.0	73.6	49.3	65.3	117.3	74.9	124.5	51.9	65.4	88.2	79.7
2/20/82 11:00	128.2	73.0	72.7	0.0	65.7	127.9	74.9	135.3	0.0	65.7	97.2	84.3
2/20/82 12:00	136.8	73.5	72.6	0.0	66.3	136.3	75.3	143.4	0.0	66.6	104.0	88.3
2/20/82 13:00	142.3	74.6	73.1	0.0	67.6	141.9	76.2	148.2	0.0	68.0	97.9	91.5
2/20/82 14:00	143.5	76.1	74.2	0.0	68.9	143.7	77.7	148.8	0.0	69.5	94.7	93.1
2/20/82 15:00	139.7	77.8	75.5	0.0	69.8	141.3	79.4	144.5	0.0	70.6	93.8	92.8
2/20/82 16:00	131.2	79.6	76.9	0.0	70.6	131.6	81.2	134.1	0.0	71.2	93.0	89.3
2/20/82 17:00	117.6	81.5	78.3	0.0	71.3	121.4	82.9	121.4	0.0	71.5	91.6	83.2
2/20/82 18:00	109.3	82.9	79.2	0.0	70.5	114.6	84.1	114.4	0.0	70.6	89.8	79.8
2/20/82 19:00	103.7	83.8	79.9	0.0	70.4	109.7	85.1	109.3	0.0	70.4	88.3	77.6
2/20/82 20:00	99.5	84.4	80.3	0.0	70.2	105.9	85.6	105.4	0.0	70.0	87.2	75.9
2/20/82 21:00	96.2	84.4	80.3	0.0	69.8	102.7	85.6	102.3	0.0	69.6	85.7	74.2
2/20/82 22:00	93.4	84.2	80.1	0.0	69.6	100.1	85.6	99.8	0.0	69.6	84.3	72.8
2/20/82 23:00	91.1	83.7	79.6	0.0	68.8	97.8	85.1	97.5	0.0	68.6	82.8	71.4
2/21/82 0:00	88.9	83.0	79.0	0.0	68.1	95.6	84.5	95.4	0.0	68.1	81.6	70.1
2/21/82 1:00	87.0	82.2	78.3	0.0	67.4	93.7	83.8	93.6	0.0	67.4	80.2	68.9
2/21/82 2:00	85.2	81.1	77.4	0.0	66.4	91.9	82.9	91.9	0.0	66.6	79.1	67.6
2/21/82 3:00	83.6	80.1	76.5	0.0	65.5	90.3	81.9	90.4	0.0	65.9	77.6	66.6
2/21/82 4:00	81.9	79.2	76.6	35.2	65.9	88.7	80.9	88.9	11.7	65.2	77.9	65.6
2/21/82 5:00	80.4	78.4	76.6	64.1	65.7	87.3	80.2	87.4	60.5	65.1	78.3	65.6
2/21/82 6:00	79.2	77.6	75.9	71.1	65.0	86.0	79.5	86.4	75.9	65.2	78.0	65.9
2/21/82 7:00	84.2	77.0	76.1	79.8	65.8	89.8	78.8	92.8	63.8	65.4	75.6	67.1
2/21/82 8:00	95.2	76.2	74.6	34.1	65.0	99.0	78.1	104.0	35.5	65.0	75.8	71.8
2/21/82 9:00	108.2	75.5	73.6	17.2	65.1	110.4	77.5	116.9	17.0	65.1	76.8	76.7
2/21/82 10:00	121.1	75.1	73.0	0.0	65.8	122.1	77.1	129.4	0.0	65.6	88.4	81.0
2/21/82 11:00	132.6	75.2	72.9	0.0	66.8	132.7	77.2	140.2	0.0	66.6	98.0	85.7
2/21/82 12:00	141.1	75.9	73.4	0.0	68.1	140.9	77.8	148.1	0.0	68.1	105.0	89.8
2/21/82 13:00	146.1	76.9	74.2	0.0	69.4	146.2	78.8	152.5	0.0	69.6	98.5	92.6
2/21/82 14:00	143.5	76.1	74.2	0.0	68.9	143.7	77.7	148.8	0.0	69.5	94.7	93.1
2/21/82 15:00	139.7	77.8	75.5	0.0	69.8	141.3	79.4	144.5	0.0	70.6	93.8	92.8
2/21/82 16:00	131.2	79.6	76.9	0.0	70.6	131.6	81.2	134.1	0.0	71.2	93.0	89.3
2/21/82 17:00	117.6	81.5	78.3	0.0	71.3	121.4	82.9	121.4	0.0	71.5	91.6	83.2
2/21/82 18:00	109.3	82.9	79.2	0.0	70.5	114.6	84.1	114.4	0.0	70.6	89.8	79.8
2/21/82 19:00	103.7	83.8	79.9	0.0	70.4	109.7	85.1	109.3	0.0	70.4	88.3	77.6
2/21/82 20:00	99.5	84.4	80.3	0.0	70.2	105.9	85.6	105.4	0.0	70.0	87.2	75.9
2/21/82 21:00	96.2	84.4	80.3	0.0	69.8	102.7	85.6	102.3	0.0	69.6	85.7	74.2
2/21/82 22:00	93.4	84.2	80.1	0.0	69.6	100.1	85.6	99.8	0.0	69.6	84.3	72.8
2/21/82 23:00	91.1	83.7	79.6	0.0	68.8	97.8	85.1	97.5	0.0	68.6	82.8	71.4

CHANNELS 108-152, 2/20/82-2/21/82

Date/Time	Ch 108	Ch 109	Ch 118	Ch 119	Ch 128	Ch 129	Ch 139	Ch 141	Ch 146	Ch 147	Ch 150	Ch 152
2/20/82 0:00	0.0	65.9	38.0	65.1	238.1	65.4	65.1				36.7	
2/20/82 1:00	31.0	65.1	45.1	65.0	218.6	65.4	65.2				35.7	
2/20/82 2:00	133.8	65.0	56.3	65.0	238.0	65.4	65.2				32.2	
2/20/82 3:00	222.0	64.9	85.3	65.4	266.4	65.1	65.5				29.0	
2/20/82 4:00	339.0	64.9	90.2	65.1	277.4	65.9	65.6				28.6	
2/20/82 5:00	301.1	65.0	108.3	65.3	266.3	66.4	65.5				35.2	
2/20/82 6:00	360.1	65.3	107.0	65.2	256.1	65.8	64.9				31.7	
2/20/82 7:00	49.7	66.8	113.8	65.1	271.9	65.4	65.4	106.5			33.8	59.3
2/20/82 8:00	0.0	72.0	113.0	65.7	250.0	65.4	65.1	171.8			36.9	125.3
2/20/82 9:00	0.0	76.8	84.0	65.1	219.8	64.8	65.4	223.2			42.3	139.6
2/20/82 10:00	0.0	80.6	61.7	64.9	176.9	65.2	66.4	254.8			48.8	219.3
2/20/82 11:00	0.0	85.3	26.7	65.1	100.8	65.4	69.3	267.1			53.4	237.6
2/20/82 12:00	0.0	89.2	0.0	65.8	71.9	65.4	72.0	266.8			53.1	234.2
2/20/82 13:00	0.0	92.4	0.0	66.4	44.0	65.2	74.9	246.6			58.0	208.5
2/20/82 14:00	0.0	94.2	0.0	67.6	12.3	65.4	77.1	207.6			58.0	164.3
2/20/82 15:00	0.0	94.1	0.0	68.7	6.5	65.7	78.3	152.6			57.1	106.3
2/20/82 16:00	0.0	90.5	0.0	69.1	12.2	65.6	78.1	81.6			55.7	27.7
2/20/82 17:00	0.0	83.1	0.0	69.4	24.4	65.1	76.4	-3.6			52.6	-2.0
2/20/82 18:00	0.0	79.3	0.0	68.8	87.2	65.7	73.8				46.3	
2/20/82 19:00	0.0	76.9	0.0	68.3	111.1	66.4	71.8				45.9	
2/20/82 20:00	0.0	75.3	0.0	67.5	113.4	65.3	70.3				45.1	
2/20/82 21:00	0.0	73.8	0.0	66.8	136.9	65.3	69.0				43.9	
2/20/82 22:00	0.0	72.5	0.0	66.4	159.7	66.2	68.0				43.5	
2/20/82 23:00	0.0	70.9	0.0	65.9	174.6	64.9	66.7				40.2	
2/21/82 0:00	0.0	69.6	5.8	65.4	176.9	65.8	66.1				40.7	
2/21/82 1:00	0.0	68.4	41.1	65.5	186.7	64.9	65.4				38.6	
2/21/82 2:00	0.0	67.4	60.6	65.5	208.4	65.8	65.6				37.5	
2/21/82 3:00	0.0	66.0	64.5	65.1	207.9	64.6	65.4				35.7	
2/21/82 4:00	49.8	65.4	90.8	65.3	236.8	66.0	65.5				36.0	
2/21/82 5:00	156.7	65.4	102.6	65.4	230.2	64.9	65.3				34.2	
2/21/82 6:00	185.1	65.4	101.0	65.2	241.0	65.6	65.2	-7.3			37.2	4.0
2/21/82 7:00	0.0	68.3	123.5	65.4	224.5	64.9	65.4	106.2			37.5	62.8
2/21/82 8:00	0.0	73.8	106.2	65.4	216.9	65.5	65.6	164.7			40.1	130.4
2/21/82 9:00	0.0	78.5	78.6	65.4	194.0	65.8	65.7	222.4			45.2	185.2
2/21/82 10:00	0.0	82.1	56.5	65.3	138.2	65.2	67.6	260.8			48.6	224.5
2/21/82 11:00	0.0	86.8	29.4	65.2	100.2	65.2	70.3	277.8			51.4	243.6
2/21/82 12:00	0.0	90.7	0.0	65.7	69.6	65.2	73.5	272.2			57.8	238.7
2/21/82 13:00	0.0	93.5	0.0	66.6	25.8	65.5	76.2	251.7			57.8	211.3
2/21/82 14:00	0.0	94.2	0.0	67.6	12.3	65.4	77.1	207.6			58.0	164.3
2/21/82 15:00	0.0	94.1	0.0	68.7	6.5	65.7	78.3	152.6			57.1	106.3
2/21/82 16:00	0.0	90.5	0.0	69.1	12.2	65.6	78.1	81.6			55.7	27.7
2/21/82 17:00	0.0	83.1	0.0	69.4	24.4	65.1	76.4	-3.6			52.6	-2.0
2/21/82 18:00	0.0	79.3	0.0	68.8	87.2	65.7	73.8				46.3	
2/21/82 19:00	0.0	76.9	0.0	68.3	111.1	66.4	71.8				45.9	
2/21/82 20:00	0.0	75.3	0.0	67.5	113.4	65.3	70.3				45.1	
2/21/82 21:00	0.0	73.8	0.0	66.8	136.9	65.3	69.0				43.9	
2/21/82 22:00	0.0	72.5	0.0	66.4	159.7	66.2	68.0				43.5	
2/21/82 23:00	0.0	70.9	0.0	65.9	174.6	64.9	66.7				40.2	

CHANNELS 156-179, 2/20/82-2/21/82

Date/Time	Ch 156	Ch 161	Ch 166	Ch 167	Ch 169	Ch 170	Ch 172	Ch 173	Ch 176	Ch 177	Ch 178	Ch 179
2/20/82 0:00					48.2	35.8		120.2		1.7	259.3	17.7
2/20/82 1:00					47.7	36.0		119.6		1.6	213.1	17.9
2/20/82 2:00					52.2	33.5		120.5		0.6	197.9	17.8
2/20/82 3:00					56.2	30.8		121.4		0.6	221.0	17.0
2/20/82 4:00					57.6	28.7		118.0		0.6	186.6	15.6
2/20/82 5:00					48.1	32.6		119.3		5.2	196.5	15.0
2/20/82 6:00			1.7	0.3	48.8	32.7		123.1	-0.1	3.1	211.8	15.5
2/20/82 7:00		60.5	62.9	49.4	54.1	31.0	29.0	123.3	80.7	1.8	208.3	16.3
2/20/82 8:00		137.5	146.7	137.1	58.5	34.2	92.4	133.8	189.5	1.5	246.3	21.2
2/20/82 9:00		192.0	217.9	217.7	63.4	39.1	153.3	143.5	270.2	3.5	227.7	27.7
2/20/82 10:00		235.8	272.7	282.4	64.5	45.1	201.0	151.6	325.4	4.9	240.5	33.8
2/20/82 11:00		261.3	308.1	323.8	53.8	52.2	230.3	161.7	351.3	5.4	292.5	35.9
2/20/82 12:00		268.6	321.9	338.0	42.6	54.4	238.0	168.9	347.3	5.4	295.3	32.1
2/20/82 13:00		258.9	315.0	322.2	40.7	55.6	223.1	174.9	314.4	3.9	326.6	32.1
2/20/82 14:00		227.7	281.9	278.9	39.5	57.4	187.4	178.3	256.3	5.3	376.6	32.9
2/20/82 15:00		181.4	225.9	213.3	33.0	57.8	136.8	173.6	181.2	9.1	386.9	28.8
2/20/82 16:00		119.3	148.9	129.0	29.8	56.8	66.4	167.0	94.9	8.5	382.5	25.5
2/20/82 17:00		30.6	45.0	29.4	31.4	54.4	11.5	158.4	14.5	2.7	330.7	24.7
2/20/82 18:00			1.2	0.0	37.8	48.6		147.2	-2.1	3.0	138.0	24.0
2/20/82 19:00					36.7	46.1		139.9		4.4	130.3	21.1
2/20/82 20:00					35.2	45.2		138.0		5.5	127.6	19.3
2/20/82 21:00					36.7	43.7		136.4		4.9	128.8	19.0
2/20/82 22:00					36.4	43.9		135.5		1.5	180.3	18.9
2/20/82 23:00					42.2	41.1		131.5		0.6	283.8	19.8
2/21/82 0:00					40.5	40.3		128.7		0.6	234.7	17.7
2/21/82 1:00					40.8	39.5		128.5		0.6	181.4	17.0
2/21/82 2:00					39.4	38.4		128.8		0.8	159.9	15.8
2/21/82 3:00					39.8	37.3		128.9		0.6	191.3	15.1
2/21/82 4:00					42.0	35.5		127.2		0.6	173.8	14.7
2/21/82 5:00					43.8	34.0		125.9		0.6	156.9	14.3
2/21/82 6:00	4.0	0.0			39.1	36.2		125.7		1.4	151.4	13.6
2/21/82 7:00	150.6	62.9		54.2	39.6	38.1	31.7	133.3	87.6	1.4	209.9	15.6
2/21/82 8:00	242.3	140.3		144.4	47.3	39.3	97.5	145.5	198.5	2.5	221.9	20.9
2/21/82 9:00	309.5	198.0		225.5	53.8	42.6	159.0	154.4	278.3	2.5	246.4	27.0
2/21/82 10:00	350.5	240.5		289.7	55.4	47.1	206.3	162.9	332.3	2.6	256.9	31.9
2/21/82 11:00	361.1	265.1		330.5	55.2	50.6	235.8	170.4	358.2	2.8	249.8	35.1
2/21/82 12:00	338.6	272.4		342.9	43.6	54.8	242.9	176.1	352.6	3.1	289.7	32.9
2/21/82 13:00	291.4	260.7		325.4	35.4	58.1	226.9	180.4	317.3	4.0	342.7	30.8
2/21/82 14:00	221.3	227.7		278.9	39.5	57.4	187.4	178.3	256.3	5.3	376.6	32.9
2/21/82 15:00	138.8	181.4		213.3	33.0	57.8	136.8	173.6	181.2	9.1	386.9	28.8
2/21/82 16:00	52.5	119.3		129.0	29.8	56.8	66.4	167.0	94.9	8.5	382.5	25.5
2/21/82 17:00		30.6		29.4	31.4	54.4	11.5	158.4	14.5	2.7	330.7	24.7
2/21/82 18:00					37.8	48.6		147.2		3.0	138.0	24.0
2/21/82 19:00					36.7	46.1		139.9		4.4	130.3	21.1
2/21/82 20:00					35.2	45.2		138.0		5.5	127.6	19.3
2/21/82 21:00					36.7	43.7		136.4		4.9	128.8	19.0
2/21/82 22:00					36.4	43.9		135.5		1.5	180.3	18.9
2/21/82 23:00					42.2	41.1		131.5		0.6	283.8	19.8

CHANNELS 1-107, 2/22/82

Date/Time	Ch 1	Ch 3	Ch 6	Ch 8	Ch 9	Ch 11	Ch 16	Ch 17	Ch 18	Ch 19	Ch 104	Ch 107
2/22/82 0:00	88.9	83.0	79.0	0.0	68.1	95.6	84.5	95.4	0.0	68.1	81.6	70.1
2/22/82 1:00	87.0	82.2	78.3	0.0	67.4	93.7	83.8	93.6	0.0	67.4	80.2	68.9
2/22/82 2:00	85.2	81.1	77.4	0.0	66.4	91.9	82.9	91.9	0.0	66.6	79.1	67.6
2/22/82 3:00	83.6	80.1	76.5	0.0	65.5	90.3	81.9	90.4	0.0	65.9	77.6	66.6
2/22/82 4:00	81.9	79.2	76.6	35.2	65.9	88.7	80.9	88.9	11.7	65.2	77.9	65.6
2/22/82 5:00	80.4	78.4	76.6	64.1	65.7	87.3	80.2	87.4	60.5	65.1	78.3	65.6
2/22/82 6:00	79.2	77.6	75.9	71.1	65.0	86.0	79.5	86.4	75.9	65.2	78.0	65.9
2/22/82 7:00	86.5		75.2	29.3	65.3	92.4	80.2	95.5	12.0	65.3		

CHANNELS 108-152, 2/22/82

Date/Time	Ch 108	Ch 109	Ch 118	Ch 119	Ch 128	Ch 129	Ch 139	Ch 141	Ch 146	Ch 147	Ch 150	Ch 152
2/22/82 0:00	0.0	69.6	5.8	65.4	176.9	65.8	66.1				40.7	
2/22/82 1:00	0.0	68.4	41.1	65.5	186.7	64.9	65.4					
2/22/82 2:00	0.0	67.4	60.6	65.5	208.4	65.8	65.6					
2/22/82 3:00	0.0	66.0	64.5	65.1	207.9	64.6	65.4					
2/22/82 4:00	49.8	65.4	90.8	65.3	236.8	66.0	65.5					
2/22/82 5:00	156.7	65.4	102.6	65.4	230.2	64.9	65.3					
2/22/82 6:00	185.1	65.4	101.0	65.2	241.0	65.6	65.2					
2/22/82 7:00	0.0	68.9	97.4	65.1	210.1	65.5	65.7					

CHANNELS 156-179, 2/22/82

Date/Time	Ch 156	Ch 161	Ch 166	Ch 167	Ch 169	Ch 170	Ch 172	Ch 173	Ch 176	Ch 177	Ch 178	Ch 179
2/22/82 0:00					40.5	40.3		128.7		0.6	234.7	17.7
2/22/82 1:00					40.8	39.5		128.5		0.6	181.4	17.0
2/22/82 2:00					39.4	38.4		128.8		0.8	159.9	15.8
2/22/82 3:00					39.8	37.3		128.9		0.6	191.3	15.1
2/22/82 4:00					42.0	35.5		127.2		0.6	173.8	14.7
2/22/82 5:00					43.8	34.0		125.9		0.6	156.9	14.3
2/22/82 6:00					39.1	36.2		125.7		1.4	151.4	13.6
2/22/82 7:00					40.0	40.0		125.0		0.0	0.0	20.0

APPENDIX B: ENERGYPLUS INPUT FILES

```
!*************
! Cell 01 - Trombe.idf
!
! Painted black; no selective surface.
!*************
 VERSION,1.1.0;
 BUILDING,Cell 01 - Trombe, !- Building Name
  0, !- Building Azimuth
  Suburbs, !- Building Terrain
  0.04, !- Loads Convergence Tolerance
  0.01, !- Temperature Convergence Tolerance
  FullInteriorAndExterior; !- Solar Distribution
 SURFACEGEOMETRY,UpperLeftCorner,CounterClockWise,WorldCoordinateSystem;
 SHADOWING CALCULATIONS,1; !- recalculate the shadowing every day
 SOLUTION ALGORITHM,CTF; !- Solution Algorithm
 INSIDE CONVECTION ALGORITHM,Detailed; !- Inside Convection Algorithm
 OUTSIDE CONVECTION ALGORITHM,Detailed; !- Outside Convection Algorithm
 TIMESTEP IN HOUR,6;
 LOCATION, LOS ALAMOS NM,     !- Location Name
   35.80000,     !- Latitude {N+ S-}
  -106.3000,     !- Longitude {W- E+}
  -7.000000,     !- TimeZoneNumber {GMT+/-}
   2158.000;     !- Elevation {m}           2158 m   = 7080 ft
 GROUNDTEMPERATURES,13,13,13,13,13,13,13,13,13,13,13,13;  ! Ground temp under slab, not
applicable here
 RUNPERIOD,
  2,             !- Begin Month
  14,            !- Begin Day Of Month
  2,             !- End Month
  22,            !- End Day Of Month
  ;              !- Day Of Week For Start Day
!*************
! Schedules
!*************
 SCHEDULETYPE,On/Off,0:1,DISCRETE;
 DAYSCHEDULE,AlwaysOnDay,On/Off,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1;
WEEKSCHEDULE,AlwaysOnWeek,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,Alw
aysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay;
 SCHEDULE,AlwaysOnSchedule,On/Off,AlwaysOnWeek,1,1,12,31;
!*************
! Materials
!*************
! "standard concrete block" -> calculated from LANL report
 MATERIAL:REGULAR, CONCRETE BLOCK,
 MediumRough,  !- Roughness
  0.1428750,   !- Thickness (m)           0.1428750
   1.3848,      !- Conductivity (W/m-K)   1.3848, suggested by Goldstein; nominal 1.731
   2189.06,    !- Density (kg/m3)         2189.06
   510.188,    !- Specific Heat (J/kg-K)  (510.188) -36% from Goldstein, nominal 797.169
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "black painted standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, BLACK PAINTED CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)       bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance   ! with flat black paint
  0.9500000,   !- Solar Absorptance   ! with flat black paint
  0.9500000;   !- Visible Absorptance ! with flat black paint
! "standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)       bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
```

```
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "5/8-in. plywood" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "5/8-in. plywood, painted white" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, WHITE PAINTED PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.25    ,   !- Solar Absorptance       painted white (unpainted was 0.70)
  0.25    ;   !- Visible Absorptance     painted white (unpainted was 0.70)
! "1/4-in. plywood" -> like above, but thinner
 MATERIAL:REGULAR, THIN PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.00635      ,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "3-1/2-in. insulation, R-11" -> B4 - 3 IN INSULATION (BLAST/HBLC library)
! modified properties to match 3.5 inch fiberglass batt specs found on www
 MATERIAL:REGULAR, R-11 INSULATION, !- Material Name
 VeryRough,  !- Roughness
  0.0889,          !- Thickness (m)          ! 3.5 in: 0.0889  3 in: 0.076200001
  0.040,   !- Conductivity (W/m-K)   ! www: 0.04592 HBLC: 0.043239430
   84.8    ,   !- Density (kg/m3)            ! www: 84.8    HBLC: 32.03693
   963.7000    ,   !- Specific Heat (J/kg-K) ! www: 963.7   HBLC: 836.8000
  0.9000000    ,   !- Thermal Emittance
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "1-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.025298400,  !- Thickness (m)              ! HBLC: 0.025298400
  0.025,     !- Conductivity (W/m-K)       ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "3.5-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, 3 1/2 IN STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.088900,  !- Thickness (m)             ! HBLC: 0.025298400
  0.025,   !- Conductivity (W/m-K)      ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "corrugated metal" -> METAL - GALVANIZED STEEL 1 / 16 IN (BLAST/HBLC library)
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 MATERIAL:REGULAR, CORRUGATED METAL, !- Material Name
 Smooth,  !- Roughness
  0.015849600,  !- Thickness (m)
   45.31492    ,   !- Conductivity (W/m-K)
   7833.028    ,   !- Density (kg/m3)
   502.0800    ,   !- Specific Heat (J/kg-K)
  0.2000000    ,   !- Thermal Emittance, was 0.90
  0.2300000    ,   !- Solar Absorptance
  0.2300000    ;   !- Visible Absorptance
! "30-lb felt" -> E3 - 3 / 8 IN FELT AND MEMBRANE (BLAST/HBLC library)
 MATERIAL:REGULAR, FELT, !- Material Name
 Rough,  !- Roughness
  0.0095402403 ,   !- Thickness (m)
  0.1902535    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   1673.600    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7500000    ,   !- Solar Absorptance
  0.7500000    ;   !- Visible Absorptance
! "90-lb rolled roofing" -> ROOFING - ASPHALT ROLL (BLAST/HBLC library)
 MATERIAL:REGULAR, ROLLED ROOFING, !- Material Name
 VeryRough,  !- Roughness
  0.0031699201 ,   !- Thickness (m)
  0.1158817    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   836.8000    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.8000000    ,   !- Solar Absorptance
  0.8000000    ;   !- Visible Absorptance
! one pane of the "Thermopane" -> GLASS - CLEAR SHEET 1 / 8 IN (BLAST/HBLC library),
modified by LANL measurements
 MATERIAL:WindowGlass,GLASS 3 / 16 IN, !- Material Name
   ! (R=.0236,TRANS=.87,VERY SMOOTH,GLASS), from 3mm clear
  SpectralAverage,,  !- Optical Data Type
  0.0047625,  !- Thickness (m)
  0.8306600,  !- Solar Transmittance at Normal Incidence    ! 0.83066, this squared gives
the measured solar transmission of 0.69
  0.0750000,  !- Solar Reflectance at Normal Incidence: Front Side
  0.0750000,  !- Solar Reflectance at Normal Incidence: Back Side
  0.8980000,  !- Visible Transmittance at Normal Incidence
  0.0810000,  !- Visible Reflectance at Normal Incidence: Front Side
  0.0810000,  !- Visible Reflectance at Normal Incidence: Back Side
  0.0000000,  !- Ir Transmittance at Normal Incidence
  0.8400000,  !- Ir Emittance at Normal Incidence: Front Side
  0.8400000,  !- Ir Emittance at Normal Incidence: Back Side
  0.9000000;  !- Conductivity (W/m-K)
 MATERIAL:WindowGas,AIR SPACE, !- Material Name
  AIR,  !- Gas Type
  0.0127;  !- Gap Width (m) = 1/2 inch
! gap in construction between bricks and surfaces
 MATERIAL:Air,BLOCK AIR SPACE,  !- Material Name
  0.1700000    ;  !- Resistance (m2-K/W)
! Sur-Wall -> CONCRETE - 1 IN MORTAR (BLAST/HBLC library), modified the thickness
 MATERIAL:Regular,Sur-Wall Masonry 1/4 inch,  !- Material Name "a commercial fiber-glass-
filled masonry material"
 Rough,  !- Roughness
  0.00635,         !- Thickness {m}
  0.7200000    ,   !- Conductivity {w/m-K}
   1858.140    ,   !- Density {kg/m3}
   830.0000    ,   !- Specific Heat {J/kg-K}
  0.9000000    ,   !- Thermal Emittance
  0.2000000    ,   !- Solar Absorptance
  0.2000000    ;   !- Visible Absorptance
 MATERIAL:Regular,Selective Surface,  !- Material Name (Berry Solar Products SunSponge
TM)
 Smooth,  !- Roughness
  1.6000000E-03,  !- Thickness (m)           ! from properties of copper
   392.6100,   !- Conductivity (W/m-K)   ! from properties of copper
   8906.260,   !- Density (kg/m3)        ! from properties of copper
   370.0000,   !- Specific Heat (J/kg-K) ! from properties of copper
  0.0700000,   !- Thermal Emittance
```

```
  0.9200000,   !- Solar Absorptance
  0.9200000;   !- Visible Absorptance
!*************
! Constructions
!*************
  CONSTRUCTION,Exterior Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      3 1/2 IN STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall Styrofoam, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      STYROFOAM,
      STYROFOAM,
      STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior Mass Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Interior Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Interior Mass Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD;
  CONSTRUCTION,Mass Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Roof, !- Construction Name
      ROLLED ROOFING, !- Outside Layer
      FELT,
      PLYWOOD,
      R-11 INSULATION,
      R-11 INSULATION,
      CORRUGATED METAL,
      STYROFOAM;
  CONSTRUCTION,Double Pane Window, !- Construction Name
      GLASS 3 / 16 IN, !- Outside Layer
      AIR SPACE,
      GLASS 3 / 16 IN;
  CONSTRUCTION, TROMBE WALL IN, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBE WALL OUT, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBESS WALL IN, !- Construction Name
      Selective Surface, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      CONCRETE BLOCK LONG;
  CONSTRUCTION, TROMBESS WALL OUT, !- Construction Name
      CONCRETE BLOCK LONG, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      Selective Surface;
```

```
!*************
! Main Zone Geometry
!*************
 ZONE,
  Main Zone,  !- Zone Name
  0.000,  !- Zone North Axis (relative to Building)
  0.000,  !- Zone X Origin [m]
  0.000,  !- Zone Y Origin [m]
  0.000,  !- Zone Z Origin [m]
  1,  !- Zone Type
  1,  !- Zone Multiplier
  3.048,  !- Zone Ceiling Height [m]
  0.000;  !- Zone Volume [m3]
 SURFACE:HEATTRANSFER,
  Main East Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.578,  0.000,  3.048,
  1.578,  0.000,  0.000,
  1.578,  2.184,  0.000,
  1.578,  2.184,  3.048;
 SURFACE:HEATTRANSFER,
  Main North Wall,   !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.578,  2.184,  3.048,
  1.578,  2.184,  0.000,
  0.000,  2.184,  0.000,
  0.000,  2.184,  3.048;
 SURFACE:HEATTRANSFER,
  Main West Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Interior Wall,  !- Construction Name
  Main Zone,  !- Zone
  OTHERSIDECOEFF,OSC,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.0,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  2.184,  3.048,
  0.000,  2.184,  0.000,
  0.000,  0.000,  0.000,
  0.000,  0.000,  3.048;
 SURFACE:HEATTRANSFER,
  Main South Wall,  !- Surface Name (This name must be "Main South Wall" so that wall
temperature from in.dat is used.)
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Trombe Wall In,  !- Construction Name
  Main Zone,  !- Zone
  OTHERZONE,Trombe North Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  0.000,  2.140,
  0.142,  0.000,  0.000,
  1.436,  0.000,  0.000,
  1.436,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
```

```
  Main South Wall - West,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  0.000,  2.140,
  0.000,  0.000,  0.000,
  0.142,  0.000,  0.000,
  0.142,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Main South Wall - Upper,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  0.000,  3.048,
  0.000,  0.000,  2.140,
  1.578,  0.000,  2.140,
  1.578,  0.000,  3.048;
 SURFACE:HEATTRANSFER,
  Main South Wall - East,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  0.000,  2.140,
  1.436,  0.000,  0.000,
  1.578,  0.000,  0.000,
  1.578,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Main Floor,  !- Surface Name
  FLOOR,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Floor,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  1.0,  !- VF to Ground
  4,  !- Number of Vertices
  1.578,  0.000,  0.000,
  0.000,  0.000,  0.000,
  0.000,  2.184,  0.000,
  1.578,  2.184,  0.000;
 SURFACE:HEATTRANSFER,
  Main Roof,  !- Surface Name
  ROOF,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Roof,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.0,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  2.184,  3.048,
  0.000,  0.000,  3.048,
  1.578,  0.000,  3.048,
  1.578,  2.184,  3.048;
!*************
! Trombe Zone Geometry
```

```
!*************
 ZONE,
  Trombe Zone,  !- Zone Name
  0.000,  !- Zone North Axis (relative to Building)
  0.000,  !- Zone X Origin [m]
  0.000,  !- Zone Y Origin [m]
  0.000,  !- Zone Z Origin [m]
  1,  !- Zone Type
  1,  !- Zone Multiplier
  2.140,  !- Zone Ceiling Height [m]
  0.000,  !- Zone Volume [m3]
  TrombeWall;  ! Zone Inside Convection Algorithm
 SURFACE:HEATTRANSFER,
  Trombe South Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Trombe Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  -0.0510,  2.140,
  0.142,  -0.0510,  0.000,
  1.436,  -0.0510,  0.000,
  1.436,  -0.0510,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe East Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe East Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  -0.0510,  2.140,
  1.436,  -0.0510,  0.000,
  1.436,  0.000,  0.000,
  1.436,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe West Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe West Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  0.000,  2.140,
  0.142,  0.000,  0.000,
  0.142,  -0.0510,  0.000,
  0.142,  -0.0510,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe North Wall,  !- Surface Name (This name must be "Trombe North Wall" so that wall
temperature from in.dat is used.)
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Trombe Wall Out,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Main South Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  0.000,  2.140,
  1.436,  0.000,  0.000,
  0.142,  0.000,  0.000,
  0.142,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe Floor,  !- Surface Name
```

```
  FLOOR,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Floor,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe Floor,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  1.0,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  -0.0510,  0.000,
  0.142,  -0.0510,  0.000,
  0.142,  0.000,  0.000,
  1.436,  0.000,  0.000;
 SURFACE:HEATTRANSFER,
  Trombe Roof,  !- Surface Name
  ROOF,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Roof,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe Roof,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.0,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  0.000,  2.140,
  0.142,  -0.0510,  2.140,
  1.436,  -0.0510,  2.140,
  1.436,  0.000,  2.140;
 SURFACE:HEATTRANSFER:SUB,
  Trombe Glazing,  !- Subsurface Name
  WINDOW,  !- Surface Type (WINDOW)
  Double Pane Window,  !- Construction Name
  Trombe South Wall,,  !- Base Surface Name and Target (if applicable)
  0.5,  !- VF to Ground
  ,  !- Window Shading Control
  ,  !- Frame/Divider Name
  1.0,  !- Window Multiplier, only applicable to Windows
  4,  !- Number of Vertices
  0.2175,  -0.0510,  1.915,
  0.2175,  -0.0510,  0.010,
  1.3605,  -0.0510,  0.010,
  1.3605,  -0.0510,  1.915;
 SURFACE:SHADING:DETACHED:BUILDING,
  Overhang,  !- Surface Name
   ,  !- Shading transmittance default is always opaque
   4,  !- Number of vertices
   0.000,   0.000,   3.556,
   0.000, -0.3556,   3.556,
   1.578, -0.3556,   3.556,
   1.578,   0.000,   3.556;
 OTHERSIDECOEFFICIENTS,OSC, !- Other Side Coefficient Name
   1,    !- Combined convective/radiative film coefficient, if 0, surface temp is set
   18.4, !- Constant Temperature [C]
   1,    !- Coefficient modifying the user selected constant temperature
   0,    !- Coefficient modifying the external dry bulb temperature
   0,    !- Coefficient modifying the ground temperature
   0,    !- Coefficient modifying the wind speed term [s/m]
   0;    !- Coefficient modifying the zone air temperature part of the equation
!*************
! Internal Gains
!*************
LIGHTS,               ! Two 500 W light bulbs controlled thermostatically
    Main Zone,        ! Zone Name
    AlwaysOnSchedule, ! Schedule Name (actually read from in.aux file)
    1000,             ! Design Level {W} (this value is not actually used either)
    0,                ! Return Air Fraction
    0.70,             ! (Fraction Radiant 0.70)   From BLAST defaults for incandescent
bulb
    0.10,             ! (Fraction Visible 0.10)   Fraction Convective = 1 - Radiant -
Visible
    0,                ! Fraction Replaceable
    GeneralLights;    ! LightsEndUseKey
!*************
```

```
! Air Loop
!*************
 AIR PRIMARY LOOP,
    Main Air Loop,             ! Primary Air Loop Name
    ,                          ! Controller List
    ,                          ! System Availability Manager List
    0.008750,             ! Primary Air Design Volumetric Flow Rate (m3/s)
    Air Loop Branches,         ! Air Loop Branch List Name
    ,                          ! Air Loop Connector List Name
    Air Loop Inlet Node,       ! Return Air Air Loop Inlet Node
    Main Zone Outlet Node,     ! ZoneEquipGroup Outlet Node
    Zone Equipment Inlet Node, ! Supply Air Path ZoneEquipGroup Inlet Nodes
    Air Loop Outlet Node;      ! Air Loop Outlet Nodes
 BRANCH LIST,
    Air Loop Branches, ! Branch List Name
    Air Loop Branch;   ! Branch Name
 BRANCH,
    Air Loop Branch,         ! Branch Name
    0.008750,           ! Maximum Branch Flow Rate (m3/s)
    OUTSIDE AIR SYSTEM,      ! Component Type
    Outside Air Sys,         ! Component Name
    Air Loop Inlet Node,     ! Component Inlet Node Name
    Outside Air Outlet Node, ! Component Outlet Node Name
    PASSIVE,                 ! Component Branch Control Type
    FAN:SIMPLE:ConstVolume,  ! Component Type
    Ventilation Fan,         ! Component Name
    Outside Air Outlet Node, ! Component Inlet Node Name
    Air Loop Outlet Node,    ! Component Outlet Node Name
    PASSIVE;                 ! Component Branch Control Type
!*************
! Fan Component
!*************
 FAN:SIMPLE:ConstVolume,
    Ventilation Fan,         ! Fan Name
    AlwaysOnSchedule,        ! Fan Schedule
    0.7,                     ! Fan Efficiency
    300.0,                   ! Delta Pressure (N/m2)
    0.008750,           ! Max Vol Flow Rate (m3/s)
    0.9,                     ! Motor Efficiency
    1.0,                     ! Motor In Air Stream Fraction
    Outside Air Outlet Node, ! Inlet Node
    Air Loop Outlet Node;    ! Outlet Node
!*************
! Outside Air Box Component
!*************
 OUTSIDE AIR SYSTEM,
       Outside Air Sys,          ! Name
       Outside Air Controllers, ! Controller List
       Outside Air Equipment,   ! Name of Air Loop Equipment List
       Outside Air Avail List;  ! Name of System Availability Manager List
 CONTROLLER LIST,
       Outside Air Controllers, ! Name
       CONTROLLER:OUTSIDE AIR,  ! Controller Type
       Outside Air Controller;  ! Controller Name
 CONTROLLER:OUTSIDE AIR,
      Outside Air Controller,       ! Name
      NO ECONOMIZER,                ! Economizer Choice
      NO RETURN AIR TEMP LIMIT,     ! Return Air Temp Limit Choice
      NO RETURN AIR ENTHALPY LIMIT, ! Return Air Enthalpy Limit Choice
      NO LOCKOUT,                   ! Lockout Choice
      FIXED MINIMUM,                ! Minimum Limit Choice
      Outside Air Outlet Node,      ! Control Node
      Outside Air Inlet Node,       ! Outside Air Inlet Node
      0.008750,               ! Minimum Outside Air Flow Rate (m3/s)
      0.008750,               ! Maximum Outside Air Flow Rate (m3/s)
      ,                             ! Temperature Limit
      ,                             ! Temperature Lower Limit
      ,                             ! Enthalpy Limit
      Exhaust Air Outlet Node,      ! Relief Air Outlet Node
      Air Loop Inlet Node;          ! Return Air Node
 AIR LOOP EQUIPMENT LIST,
```

```
      Outside Air Equipment, ! Name
      OUTSIDE AIR MIXER,     ! System Component
      Outside Air Box;       ! Component Name
 OUTSIDE AIR MIXER,
      Outside Air Box,         ! Outside Air Mixer Name
      Outside Air Outlet Node, ! Mixed Air Node (Outlet)
      Outside Air Inlet Node,  ! Outside Air Stream Node (Inlet)
      Exhaust Air Outlet Node, ! Relief Air Stream Node (Outlet)
      Air Loop Inlet Node;     ! Return Air Stream Node (Inlet)
 OUTSIDE AIR INLET NODE LIST,
      Outside Air Inlet Nodes; ! Name
 NODE LIST,
      Outside Air Inlet Nodes, ! Node List Name
      Outside Air Inlet Node;  ! Node Name
 SYSTEM AVAILABILITY MANAGER LIST,
      Outside Air Avail List,                ! Name
      SYSTEM AVAILABILITY MANAGER:SCHEDULED, ! System Availability Manager Type
      Outside Air Avail;                     ! System Availability Manager Name
 SYSTEM AVAILABILITY MANAGER:SCHEDULED,
      Outside Air Avail, ! Name
      AlwaysOnSchedule;  ! Schedule Name
!*************
! Zone Equipment
!*************
 CONTROLLED ZONE EQUIP CONFIGURATION,
    Main Zone,             ! Zone Name
    Main Zone Equipment,   ! Zone Equipment List Name
    Main Zone Inlets,      ! Zone Inlet Nodes
    ,                      ! Zone Exhaust Nodes
    Main Zone Node,        ! Zone Air Node Name
    Main Zone Outlet Node; ! Zone Return Air Node Name
 NODE LIST,
    Main Zone Inlets,     ! Node List Name
    Main Zone Inlet Node; ! Node Name
 ZONE EQUIPMENT LIST,
    Main Zone Equipment,  ! Zone Equipment List Name
    DIRECT AIR,           ! Zone Equipment Type
    Main Zone Direct Air, ! Zone Equipment Name
    1,                    ! Cooling Priority
    1;                    ! Heating Priority
 DIRECT AIR,
    Main Zone Direct Air, ! Direct Air Name
    AlwaysOnSchedule,     ! Schedule Name
    Main Zone Inlet Node, ! Zone Supply Air Node Name
    0.008750;        ! Maximum Air Flow Rate (m3/s)
 ZONE SUPPLY AIR PATH,
    Zone Supply Air Path,      ! Supply Air Path Name
    Zone Equipment Inlet Node, ! Air Path Inlet Node
    ZONE SPLITTER,             ! System Component Type
    Zone Splitter;             ! Component Name
 ZONE SPLITTER,
    Zone Splitter,             ! Splitter Name
    Zone Equipment Inlet Node, ! Inlet Node
    Main Zone Inlet Node;      ! Outlet Node
!*************
! Reporting
!*************
 DEBUG OUTPUT,0,0; !- 0 is off, 1 is on
 REPORT,Variable Dictionary;
 REPORT,Surfaces,DXF;
 REPORT VARIABLE,*,Outdoor Dry Bulb,Timestep;
 REPORT VARIABLE,*,Solar Azimuth Angle,Timestep;
 REPORT VARIABLE,*,Solar Altitude Angle,Timestep;
 REPORT VARIABLE,*,Solar Hour Angle,Timestep;
 REPORT VARIABLE,*,Sky Temperature,Timestep;
 REPORT VARIABLE,*,Direct Solar,Timestep;
 REPORT VARIABLE,*,Diffuse Solar,Timestep;
 REPORT VARIABLE,*,Auxiliary Heat,Timestep;
 REPORT VARIABLE,*,Adjoining Globe Temperature,Timestep;
 REPORT VARIABLE,*,Mean Radiant Temperature,Timestep;
 REPORT VARIABLE,*,Zone/Sys Air Temp,Timestep;
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 REPORT VARIABLE,*,Zone Globe Temperature,Timestep;
 REPORT VARIABLE,*,Opaque Surface Inside Face Conduction,Timestep;
 REPORT VARIABLE,*,Lights-Total Heat Gain,Timestep;
 REPORT VARIABLE,*,Direct Air Sensible Cooling Rate,Timestep;
 REPORT VARIABLE,*,Zone/Sys Sensible Cooling Rate,Timestep;
 REPORT VARIABLE,*,Surface Int Convection Coeff,Timestep;
 REPORT VARIABLE,*,Surface Ext Convection Coeff,Timestep;
 REPORT VARIABLE,*,Surface Inside Temperature,Timestep;
 REPORT VARIABLE,*,Surface Outside Temperature,Timestep;
 REPORT VARIABLE,*,Surface Ext Sunlit Area,Timestep;
 REPORT VARIABLE,*,Surface Ext Solar Incident,Timestep;



!*************
! Cell 02 - TrombeSS.idf
!
! Selective surface.
!
! This cell should be identical to Cell 01 except for the following:
!   1. Selective surface construction on Trombe wall.
!   2. OSC on the east wall (instead of west wallfor Cell 01).
!   3. Shaded by Cell 3 on the west side.
!*************
 VERSION,1.1.0;
 BUILDING,Cell 02 - TrombeSS, !- Building Name
  0, !- Building Azimuth
  Suburbs, !- Building Terrain
  0.04, !- Loads Convergence Tolerance
  0.01, !- Temperature Convergence Tolerance
  FullInteriorAndExterior; !- Solar Distribution
 SURFACEGEOMETRY,UpperLeftCorner,CounterClockWise,WorldCoordinateSystem;
 SHADOWING CALCULATIONS,1; !- recalculate the shadowing every day
 SOLUTION ALGORITHM,CTF; !- Solution Algorithm
 INSIDE CONVECTION ALGORITHM,Detailed; !- Inside Convection Algorithm
 OUTSIDE CONVECTION ALGORITHM,Detailed; !- Outside Convection Algorithm
 TIMESTEP IN HOUR,6;
 LOCATION, LOS ALAMOS NM,     !- Location Name
   35.80000,     !- Latitude {N+ S-}
  -106.3000,     !- Longitude {W- E+}
  -7.000000,     !- TimeZoneNumber {GMT+/-}
   2158.000;     !- Elevation {m}           2158 m   = 7080 ft
 GROUNDTEMPERATURES,13,13,13,13,13,13,13,13,13,13,13,13;  ! Ground temp under slab, not
applicable here
 RUNPERIOD,
  2,             !- Begin Month
  14,            !- Begin Day Of Month
  2,             !- End Month
  22,            !- End Day Of Month
  ;              !- Day Of Week For Start Day
!*************
! Schedules
!*************
 SCHEDULETYPE,On/Off,0:1,DISCRETE;
 DAYSCHEDULE,AlwaysOnDay,On/Off,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1;
WEEKSCHEDULE,AlwaysOnWeek,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,Alw
aysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay;
 SCHEDULE,AlwaysOnSchedule,On/Off,AlwaysOnWeek,1,1,12,31;
!*************
! Materials
!*************
! "standard concrete block" -> calculated from LANL report
 MATERIAL:REGULAR, CONCRETE BLOCK,
 MediumRough,  !- Roughness
  0.1428750,   !- Thickness (m)           0.1428750
   1.3848,      !- Conductivity (W/m-K)   1.3848, suggested by Goldstein; nominal 1.731
   2189.06,    !- Density (kg/m3)         2189.06
   510.188,    !- Specific Heat (J/kg-K)  (510.188) -36% from Goldstein, nominal 797.169
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
```

```
! "black painted standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, BLACK PAINTED CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)       bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance   ! with flat black paint
  0.9500000,   !- Solar Absorptance   ! with flat black paint
  0.9500000;   !- Visible Absorptance ! with flat black paint
! "standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)       bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "5/8-in. plywood" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "5/8-in. plywood, painted white" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, WHITE PAINTED PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.25    ,   !- Solar Absorptance       painted white (unpainted was 0.70)
  0.25    ;   !- Visible Absorptance     painted white (unpainted was 0.70)
! "1/4-in. plywood" -> like above, but thinner
 MATERIAL:REGULAR, THIN PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.00635      ,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "3-1/2-in. insulation, R-11" -> B4 - 3 IN INSULATION (BLAST/HBLC library)
! modified properties to match 3.5 inch fiberglass batt specs found on www
 MATERIAL:REGULAR, R-11 INSULATION, !- Material Name
 VeryRough,  !- Roughness
  0.0889,          !- Thickness (m)          ! 3.5 in: 0.0889  3 in: 0.076200001
  0.040,   !- Conductivity (W/m-K)   ! www: 0.04592 HBLC: 0.043239430
   84.8    ,   !- Density (kg/m3)            ! www: 84.8    HBLC: 32.03693
   963.7000    ,   !- Specific Heat (J/kg-K) ! www: 963.7   HBLC: 836.8000
  0.9000000    ,   !- Thermal Emittance
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "1-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.025298400,  !- Thickness (m)              ! HBLC: 0.025298400
  0.025,     !- Conductivity (W/m-K)       ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
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  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "3.5-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, 3 1/2 IN STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.088900,  !- Thickness (m)              ! HBLC: 0.025298400
  0.025,   !- Conductivity (W/m-K)      ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "corrugated metal" -> METAL - GALVANIZED STEEL 1 / 16 IN (BLAST/HBLC library)
 MATERIAL:REGULAR, CORRUGATED METAL, !- Material Name
 Smooth,  !- Roughness
  0.015849600,  !- Thickness (m)
   45.31492    ,   !- Conductivity (W/m-K)
   7833.028    ,   !- Density (kg/m3)
   502.0800    ,   !- Specific Heat (J/kg-K)
  0.2000000    ,   !- Thermal Emittance, was 0.90
  0.2300000    ,   !- Solar Absorptance
  0.2300000    ;   !- Visible Absorptance
! "30-lb felt" -> E3 - 3 / 8 IN FELT AND MEMBRANE (BLAST/HBLC library)
 MATERIAL:REGULAR, FELT, !- Material Name
 Rough,  !- Roughness
  0.0095402403 ,   !- Thickness (m)
  0.1902535    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   1673.600    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7500000    ,   !- Solar Absorptance
  0.7500000    ;   !- Visible Absorptance
! "90-lb rolled roofing" -> ROOFING - ASPHALT ROLL (BLAST/HBLC library)
 MATERIAL:REGULAR, ROLLED ROOFING, !- Material Name
 VeryRough,  !- Roughness
  0.0031699201 ,   !- Thickness (m)
  0.1158817    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   836.8000    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.8000000    ,   !- Solar Absorptance
  0.8000000    ;   !- Visible Absorptance
! one pane of the "Thermopane" -> GLASS - CLEAR SHEET 1 / 8 IN (BLAST/HBLC library),
modified by LANL measurements
 MATERIAL:WindowGlass,GLASS 3 / 16 IN, !- Material Name
   ! (R=.0236,TRANS=.87,VERY SMOOTH,GLASS), from 3mm clear
  SpectralAverage,,  !- Optical Data Type
  0.0047625,  !- Thickness (m)
  0.8306600,  !- Solar Transmittance at Normal Incidence    ! 0.83066, this squared gives
the measured solar transmission of 0.69
  0.0750000,  !- Solar Reflectance at Normal Incidence: Front Side
  0.0750000,  !- Solar Reflectance at Normal Incidence: Back Side
  0.8980000,  !- Visible Transmittance at Normal Incidence
  0.0810000,  !- Visible Reflectance at Normal Incidence: Front Side
  0.0810000,  !- Visible Reflectance at Normal Incidence: Back Side
  0.0000000,  !- Ir Transmittance at Normal Incidence
  0.8400000,  !- Ir Emittance at Normal Incidence: Front Side
  0.8400000,  !- Ir Emittance at Normal Incidence: Back Side
  0.9000000;  !- Conductivity (W/m-K)
 MATERIAL:WindowGas,AIR SPACE, !- Material Name
  AIR,  !- Gas Type
  0.0127;  !- Gap Width (m) = 1/2 inch
! gap in construction between bricks and surfaces
 MATERIAL:Air,BLOCK AIR SPACE,  !- Material Name
  0.1700000    ;  !- Resistance (m2-K/W)
! Sur-Wall -> CONCRETE - 1 IN MORTAR (BLAST/HBLC library), modified the thickness
 MATERIAL:Regular,Sur-Wall Masonry 1/4 inch,  !- Material Name "a commercial fiber-glass-
filled masonry material"
 Rough,  !- Roughness
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  0.00635,         !- Thickness {m}
  0.7200000    ,   !- Conductivity {w/m-K}
   1858.140    ,   !- Density {kg/m3}
   830.0000    ,   !- Specific Heat {J/kg-K}
  0.9000000    ,   !- Thermal Emittance
  0.2000000    ,   !- Solar Absorptance
  0.2000000    ;   !- Visible Absorptance
 MATERIAL:Regular,Selective Surface,  !- Material Name (Berry Solar Products SunSponge
TM)
 Smooth,  !- Roughness
  1.6000000E-03,  !- Thickness (m)           ! from properties of copper
   392.6100,   !- Conductivity (W/m-K)   ! from properties of copper
   8906.260,   !- Density (kg/m3)        ! from properties of copper
   370.0000,   !- Specific Heat (J/kg-K) ! from properties of copper
  0.0700000,   !- Thermal Emittance
  0.9200000,   !- Solar Absorptance
  0.9200000;   !- Visible Absorptance
!*************
! Constructions
!*************
  CONSTRUCTION,Exterior Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      3 1/2 IN STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall Styrofoam, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      STYROFOAM,
      STYROFOAM,
      STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior Mass Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Interior Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Interior Mass Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD;
  CONSTRUCTION,Mass Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Roof, !- Construction Name
      ROLLED ROOFING, !- Outside Layer
      FELT,
      PLYWOOD,
      R-11 INSULATION,
      R-11 INSULATION,
      CORRUGATED METAL,
      STYROFOAM;
  CONSTRUCTION,Double Pane Window, !- Construction Name
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      GLASS 3 / 16 IN, !- Outside Layer
      AIR SPACE,
      GLASS 3 / 16 IN;
  CONSTRUCTION, TROMBE WALL IN, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBE WALL OUT, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBESS WALL IN, !- Construction Name
      Selective Surface, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      CONCRETE BLOCK LONG;
  CONSTRUCTION, TROMBESS WALL OUT, !- Construction Name
      CONCRETE BLOCK LONG, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      Selective Surface;
!*************
! Main Zone Geometry
!*************
 ZONE,
  Main Zone,  !- Zone Name
  0.000,  !- Zone North Axis (relative to Building)
  0.000,  !- Zone X Origin [m]
  0.000,  !- Zone Y Origin [m]
  0.000,  !- Zone Z Origin [m]
  1,  !- Zone Type
  1,  !- Zone Multiplier
  3.048,  !- Zone Ceiling Height [m]
  0.000;  !- Zone Volume [m3]
 SURFACE:HEATTRANSFER,
  Main East Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Interior Wall,  !- Construction Name
  Main Zone,  !- Zone
  OTHERSIDECOEFF,OSC,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.578,  0.000,  3.048,
  1.578,  0.000,  0.000,
  1.578,  2.184,  0.000,
  1.578,  2.184,  3.048;
 SURFACE:HEATTRANSFER,
  Main North Wall,   !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.578,  2.184,  3.048,
  1.578,  2.184,  0.000,
  0.000,  2.184,  0.000,
  0.000,  2.184,  3.048;
 SURFACE:HEATTRANSFER,
  Main West Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.0,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  2.184,  3.048,
  0.000,  2.184,  0.000,
  0.000,  0.000,  0.000,
  0.000,  0.000,  3.048;
 SURFACE:HEATTRANSFER,
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  Main South Wall,  !- Surface Name (This name must be "Main South Wall" so that wall
temperature from in.dat is used.)
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  TrombeSS Wall In,  !- Construction Name
  Main Zone,  !- Zone
  OTHERZONE,Trombe North Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  0.000,  2.140,
  0.142,  0.000,  0.000,
  1.436,  0.000,  0.000,
  1.436,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Main South Wall - West,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  0.000,  2.140,
  0.000,  0.000,  0.000,
  0.142,  0.000,  0.000,
  0.142,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Main South Wall - Upper,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  0.000,  3.048,
  0.000,  0.000,  2.140,
  1.578,  0.000,  2.140,
  1.578,  0.000,  3.048;
 SURFACE:HEATTRANSFER,
  Main South Wall - East,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  0.000,  2.140,
  1.436,  0.000,  0.000,
  1.578,  0.000,  0.000,
  1.578,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Main Floor,  !- Surface Name
  FLOOR,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Floor,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  1.0,  !- VF to Ground
  4,  !- Number of Vertices
  1.578,  0.000,  0.000,
  0.000,  0.000,  0.000,
  0.000,  2.184,  0.000,
  1.578,  2.184,  0.000;
 SURFACE:HEATTRANSFER,
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```
  Main Roof,  !- Surface Name
  ROOF,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Roof,  !- Construction Name
  Main Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.0,  !- VF to Ground
  4,  !- Number of Vertices
  0.000,  2.184,  3.048,
  0.000,  0.000,  3.048,
  1.578,  0.000,  3.048,
  1.578,  2.184,  3.048;
!*************
! Trombe Zone Geometry
!*************
 ZONE,
  Trombe Zone,  !- Zone Name
  0.000,  !- Zone North Axis (relative to Building)
  0.000,  !- Zone X Origin [m]
  0.000,  !- Zone Y Origin [m]
  0.000,  !- Zone Z Origin [m]
  1,  !- Zone Type
  1,  !- Zone Multiplier
  2.140,  !- Zone Ceiling Height [m]
  0.000,  !- Zone Volume [m3]
  TrombeWall;  ! Zone Inside Convection Algorithm
 SURFACE:HEATTRANSFER,
  Trombe South Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Trombe Zone,  !- Zone
  EXTERIORENVIRONMENT,,  !- Exterior Conditions and Target (if applicable)
  SUNEXPOSED,  !- Solar Exposure
  WINDEXPOSED,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  -0.0510,  2.140,
  0.142,  -0.0510,  0.000,
  1.436,  -0.0510,  0.000,
  1.436,  -0.0510,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe East Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe East Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  -0.0510,  2.140,
  1.436,  -0.0510,  0.000,
  1.436,  0.000,  0.000,
  1.436,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe West Wall,  !- Surface Name
  WALL,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe West Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  0.000,  2.140,
  0.142,  0.000,  0.000,
  0.142,  -0.0510,  0.000,
  0.142,  -0.0510,  2.140;
 SURFACE:HEATTRANSFER,
```

```
  Trombe North Wall,  !- Surface Name (This name must be "Trombe North Wall" so that wall
temperature from in.dat is used.)
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  TrombeSS Wall Out,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Main South Wall,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.5,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  0.000,  2.140,
  1.436,  0.000,  0.000,
  0.142,  0.000,  0.000,
  0.142,  0.000,  2.140;
 SURFACE:HEATTRANSFER,
  Trombe Floor,  !- Surface Name
  FLOOR,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Floor,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe Floor,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  1.0,  !- VF to Ground
  4,  !- Number of Vertices
  1.436,  -0.0510,  0.000,
  0.142,  -0.0510,  0.000,
  0.142,  0.000,  0.000,
  1.436,  0.000,  0.000;
 SURFACE:HEATTRANSFER,
  Trombe Roof,  !- Surface Name
  ROOF,  !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Roof,  !- Construction Name
  Trombe Zone,  !- Zone
  OTHERZONE,Trombe Roof,  !- Exterior Conditions and Target (if applicable)
  NOSUN,  !- Solar Exposure
  NOWIND,  !- Wind Exposure
  0.0,  !- VF to Ground
  4,  !- Number of Vertices
  0.142,  0.000,  2.140,
  0.142,  -0.0510,  2.140,
  1.436,  -0.0510,  2.140,
  1.436,  0.000,  2.140;
 SURFACE:HEATTRANSFER:SUB,
  Trombe Glazing,  !- Subsurface Name
  WINDOW,  !- Surface Type (WINDOW)
  Double Pane Window,  !- Construction Name
  Trombe South Wall,,  !- Base Surface Name and Target (if applicable)
  0.5,  !- VF to Ground
  ,  !- Window Shading Control
  ,  !- Frame/Divider Name
  1.0,  !- Window Multiplier, only applicable to Windows
  4,  !- Number of Vertices
  0.2175,  -0.0510,  1.915,
  0.2175,  -0.0510,  0.010,
  1.3605,  -0.0510,  0.010,
  1.3605,  -0.0510,  1.915;
 SURFACE:SHADING:DETACHED:BUILDING,
  Cell 3,  !- Surface Name
  ,  !- Shading transmittance default is always opaque
  4,  !-RectangularOverhang
  -1.370,   2.184,   3.556,
  -1.370,   2.184,   0.000,
  -1.370,   0.000,   0.000,
  -1.370,   0.000,   3.556;
 SURFACE:SHADING:DETACHED:BUILDING,
  Overhang,  !- Surface Name
   ,  !- Shading transmittance default is always opaque
   4,  !- Number of vertices
   0.000,   0.000,   3.556,
   0.000, -0.3556,   3.556,
   1.578, -0.3556,   3.556,
```

```
   1.578,   0.000,   3.556;
 OTHERSIDECOEFFICIENTS,OSC, !- Other Side Coefficient Name
   1,    !- Combined convective/radiative film coefficient, if 0, surface temp is set
   18.4, !- Constant Temperature [C]
   1,    !- Coefficient modifying the user selected constant temperature
   0,    !- Coefficient modifying the external dry bulb temperature
   0,    !- Coefficient modifying the ground temperature
   0,    !- Coefficient modifying the wind speed term [s/m]
   0;    !- Coefficient modifying the zone air temperature part of the equation
!*************
! Internal Gains
!*************
LIGHTS,               ! Two 500 W light bulbs controlled thermostatically
    Main Zone,        ! Zone Name
    AlwaysOnSchedule, ! Schedule Name (actually read from in.aux file)
    1000,             ! Design Level {W} (this value is not actually used either)
    0,                ! Return Air Fraction
    0.70,             ! (Fraction Radiant 0.70)   From BLAST defaults for incandescent
bulb
    0.10,             ! (Fraction Visible 0.10)   Fraction Convective = 1 - Radiant -
Visible
    0,                ! Fraction Replaceable
    GeneralLights;    ! LightsEndUseKey
!*************
! Air Loop
!*************
 AIR PRIMARY LOOP,
    Main Air Loop,             ! Primary Air Loop Name
    ,                          ! Controller List
    ,                          ! System Availability Manager List
    0.008750,             ! Primary Air Design Volumetric Flow Rate (m3/s)
    Air Loop Branches,         ! Air Loop Branch List Name
    ,                          ! Air Loop Connector List Name
    Air Loop Inlet Node,       ! Return Air Air Loop Inlet Node
    Main Zone Outlet Node,     ! ZoneEquipGroup Outlet Node
    Zone Equipment Inlet Node, ! Supply Air Path ZoneEquipGroup Inlet Nodes
    Air Loop Outlet Node;      ! Air Loop Outlet Nodes
 BRANCH LIST,
    Air Loop Branches, ! Branch List Name
    Air Loop Branch;   ! Branch Name
 BRANCH,
    Air Loop Branch,          ! Branch Name
    0.008750,           ! Maximum Branch Flow Rate (m3/s)
    OUTSIDE AIR SYSTEM,       ! Component Type
    Outside Air Sys,          ! Component Name
    Air Loop Inlet Node,      ! Component Inlet Node Name
    Outside Air Outlet Node, ! Component Outlet Node Name
    PASSIVE,                  ! Component Branch Control Type
    FAN:SIMPLE:ConstVolume,  ! Component Type
    Ventilation Fan,          ! Component Name
    Outside Air Outlet Node, ! Component Inlet Node Name
    Air Loop Outlet Node,     ! Component Outlet Node Name
    PASSIVE;                  ! Component Branch Control Type
!*************
! Fan Component
!*************
 FAN:SIMPLE:ConstVolume,
    Ventilation Fan,          ! Fan Name
    AlwaysOnSchedule,         ! Fan Schedule
    0.7,                      ! Fan Efficiency
    300.0,                    ! Delta Pressure (N/m2)
    0.008750,           ! Max Vol Flow Rate (m3/s)
    0.9,                      ! Motor Efficiency
    1.0,                      ! Motor In Air Stream Fraction
    Outside Air Outlet Node, ! Inlet Node
    Air Loop Outlet Node;     ! Outlet Node
!*************
! Outside Air Box Component
!*************
 OUTSIDE AIR SYSTEM,
       Outside Air Sys,         ! Name
```

```
       Outside Air Controllers, ! Controller List
       Outside Air Equipment,   ! Name of Air Loop Equipment List
       Outside Air Avail List;  ! Name of System Availability Manager List
 CONTROLLER LIST,
       Outside Air Controllers, ! Name
       CONTROLLER:OUTSIDE AIR,  ! Controller Type
       Outside Air Controller;  ! Controller Name
 CONTROLLER:OUTSIDE AIR,
      Outside Air Controller,       ! Name
      NO ECONOMIZER,                ! Economizer Choice
      NO RETURN AIR TEMP LIMIT,     ! Return Air Temp Limit Choice
      NO RETURN AIR ENTHALPY LIMIT, ! Return Air Enthalpy Limit Choice
      NO LOCKOUT,                   ! Lockout Choice
      FIXED MINIMUM,                ! Minimum Limit Choice
      Outside Air Outlet Node,      ! Control Node
      Outside Air Inlet Node,       ! Outside Air Inlet Node
      0.008750,                ! Minimum Outside Air Flow Rate (m3/s)
      0.008750,                ! Maximum Outside Air Flow Rate (m3/s)
      ,                             ! Temperature Limit
      ,                             ! Temperature Lower Limit
      ,                             ! Enthalpy Limit
      Exhaust Air Outlet Node,      ! Relief Air Outlet Node
      Air Loop Inlet Node;          ! Return Air Node
 AIR LOOP EQUIPMENT LIST,
      Outside Air Equipment, ! Name
      OUTSIDE AIR MIXER,     ! System Component
      Outside Air Box;       ! Component Name
 OUTSIDE AIR MIXER,
      Outside Air Box,         ! Outside Air Mixer Name
      Outside Air Outlet Node, ! Mixed Air Node (Outlet)
      Outside Air Inlet Node,  ! Outside Air Stream Node (Inlet)
      Exhaust Air Outlet Node, ! Relief Air Stream Node (Outlet)
      Air Loop Inlet Node;     ! Return Air Stream Node (Inlet)
 OUTSIDE AIR INLET NODE LIST,
      Outside Air Inlet Nodes; ! Name
 NODE LIST,
      Outside Air Inlet Nodes, ! Node List Name
      Outside Air Inlet Node;  ! Node Name
 SYSTEM AVAILABILITY MANAGER LIST,
      Outside Air Avail List,               ! Name
      SYSTEM AVAILABILITY MANAGER:SCHEDULED, ! System Availability Manager Type
      Outside Air Avail;                    ! System Availability Manager Name
 SYSTEM AVAILABILITY MANAGER:SCHEDULED,
      Outside Air Avail, ! Name
      AlwaysOnSchedule;  ! Schedule Name
!*************
! Zone Equipment
!*************
 CONTROLLED ZONE EQUIP CONFIGURATION,
    Main Zone,             ! Zone Name
    Main Zone Equipment,   ! Zone Equipment List Name
    Main Zone Inlets,      ! Zone Inlet Nodes
    ,                      ! Zone Exhaust Nodes
    Main Zone Node,        ! Zone Air Node Name
    Main Zone Outlet Node; ! Zone Return Air Node Name
 NODE LIST,
    Main Zone Inlets,     ! Node List Name
    Main Zone Inlet Node; ! Node Name
 ZONE EQUIPMENT LIST,
    Main Zone Equipment,  ! Zone Equipment List Name
    DIRECT AIR,           ! Zone Equipment Type
    Main Zone Direct Air, ! Zone Equipment Name
    1,                    ! Cooling Priority
    1;                    ! Heating Priority
 DIRECT AIR,
    Main Zone Direct Air, ! Direct Air Name
    AlwaysOnSchedule,     ! Schedule Name
    Main Zone Inlet Node, ! Zone Supply Air Node Name
    0.008750;        ! Maximum Air Flow Rate (m3/s)
 ZONE SUPPLY AIR PATH,
    Zone Supply Air Path,      ! Supply Air Path Name
```

```
    Zone Equipment Inlet Node, ! Air Path Inlet Node
    ZONE SPLITTER,             ! System Component Type
    Zone Splitter;             ! Component Name
 ZONE SPLITTER,
    Zone Splitter,             ! Splitter Name
    Zone Equipment Inlet Node, ! Inlet Node
    Main Zone Inlet Node;      ! Outlet Node
!*************
! Reporting
!*************
 DEBUG OUTPUT,0,0; !- 0 is off, 1 is on
 REPORT,Variable Dictionary;
 REPORT,Surfaces,DXF;
 REPORT VARIABLE,*,Outdoor Dry Bulb,Timestep;
 REPORT VARIABLE,*,Solar Azimuth Angle,Timestep;
 REPORT VARIABLE,*,Solar Altitude Angle,Timestep;
 REPORT VARIABLE,*,Solar Hour Angle,Timestep;
 REPORT VARIABLE,*,Sky Temperature,Timestep;
 REPORT VARIABLE,*,Direct Solar,Timestep;
 REPORT VARIABLE,*,Diffuse Solar,Timestep;
 REPORT VARIABLE,*,Auxiliary Heat,Timestep;
 REPORT VARIABLE,*,Adjoining Globe Temperature,Timestep;
 REPORT VARIABLE,*,Mean Radiant Temperature,Timestep;
 REPORT VARIABLE,*,Zone/Sys Air Temp,Timestep;
 REPORT VARIABLE,*,Zone Globe Temperature,Timestep;
 REPORT VARIABLE,*,Opaque Surface Inside Face Conduction,Timestep;
 REPORT VARIABLE,*,Lights-Total Heat Gain,Timestep;
 REPORT VARIABLE,*,Direct Air Sensible Cooling Rate,Timestep;
 REPORT VARIABLE,*,Zone/Sys Sensible Cooling Rate,Timestep;
 REPORT VARIABLE,*,Surface Int Convection Coeff,Timestep;
 REPORT VARIABLE,*,Surface Ext Convection Coeff,Timestep;
 REPORT VARIABLE,*,Surface Inside Temperature,Timestep;
 REPORT VARIABLE,*,Surface Outside Temperature,Timestep;
 REPORT VARIABLE,*,Surface Ext Sunlit Area,Timestep;
 REPORT VARIABLE,*,Surface Ext Solar Incident,Timestep;



!*************
! Cell 11 - Direct Gain.idf
!
! South facing double pane window with massive floor.
!*************
 VERSION,1.1.0;
 BUILDING,Cell 11 - Direct Gain, !- Building Name
  0, !- Building Azimuth
  Suburbs, !- Building Terrain
  0.04, !- Loads Convergence Tolerance
  0.01, !- Temperature Convergence Tolerance
  FullInteriorAndExterior; !- Solar Distribution
 SURFACEGEOMETRY,UpperLeftCorner,CounterClockWise,WorldCoordinateSystem;
 SHADOWING CALCULATIONS,1; !- recalculate the shadowing every day
 SOLUTION ALGORITHM,CTF; !- Solution Algorithm
 INSIDE CONVECTION ALGORITHM,Detailed; !- Inside Convection Algorithm
 OUTSIDE CONVECTION ALGORITHM,Detailed; !- Outside Convection Algorithm
 TIMESTEP IN HOUR,6;
 LOCATION, LOS ALAMOS NM,     !- Location Name
   35.80000,     !- Latitude {N+ S-}
  -106.3000,     !- Longitude {W- E+}
  -7.000000,     !- TimeZoneNumber {GMT+/-}
   2158.000;     !- Elevation {m}           2158 m   = 7080 ft
 GROUNDTEMPERATURES,13,13,13,13,13,13,13,13,13,13,13,13;  ! Ground temp under slab, not
applicable here
 RUNPERIOD,
  2,             !- Begin Month
  14,            !- Begin Day Of Month
  2,             !- End Month
  22,            !- End Day Of Month
  ;              !- Day Of Week For Start Day
!*************
! Schedules
```

```
!*************
 SCHEDULETYPE,On/Off,0:1,DISCRETE;
 DAYSCHEDULE,AlwaysOnDay,On/Off,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1;
WEEKSCHEDULE,AlwaysOnWeek,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,Alw
aysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay;
 SCHEDULE,AlwaysOnSchedule,On/Off,AlwaysOnWeek,1,1,12,31;
!*************
! Materials
!*************
! "standard concrete block" -> calculated from LANL report
 MATERIAL:REGULAR, CONCRETE BLOCK,
 MediumRough,  !- Roughness
  0.1428750,   !- Thickness (m)          0.1428750
   1.3848,      !- Conductivity (W/m-K)   1.3848, suggested by Goldstein; nominal 1.731
   2189.06,    !- Density (kg/m3)         2189.06
   510.188,    !- Specific Heat (J/kg-K)  (510.188) -36% from Goldstein, nominal 797.169
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "black painted standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, BLACK PAINTED CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)      bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance   ! with flat black paint
  0.9500000,   !- Solar Absorptance   ! with flat black paint
  0.9500000;   !- Visible Absorptance ! with flat black paint
! "standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)      bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "5/8-in. plywood" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "5/8-in. plywood, painted white" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, WHITE PAINTED PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.25    ,   !- Solar Absorptance       painted white (unpainted was 0.70)
  0.25    ;   !- Visible Absorptance     painted white (unpainted was 0.70)
! "1/4-in. plywood" -> like above, but thinner
 MATERIAL:REGULAR, THIN PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.00635      ,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "3-1/2-in. insulation, R-11" -> B4 - 3 IN INSULATION (BLAST/HBLC library)
! modified properties to match 3.5 inch fiberglass batt specs found on www
```

```
 MATERIAL:REGULAR, R-11 INSULATION, !- Material Name
 VeryRough,  !- Roughness
  0.0889,          !- Thickness (m)          ! 3.5 in: 0.0889  3 in: 0.076200001
  0.040,   !- Conductivity (W/m-K)   ! www: 0.04592 HBLC: 0.043239430
   84.8    ,   !- Density (kg/m3)           ! www: 84.8    HBLC: 32.03693
   963.7000    ,   !- Specific Heat (J/kg-K) ! www: 963.7   HBLC: 836.8000
  0.9000000    ,   !- Thermal Emittance
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "1-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.025298400,  !- Thickness (m)              ! HBLC: 0.025298400
  0.025,     !- Conductivity (W/m-K)       ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "3.5-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, 3 1/2 IN STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.088900,  !- Thickness (m)             ! HBLC: 0.025298400
  0.025,   !- Conductivity (W/m-K)      ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "corrugated metal" -> METAL - GALVANIZED STEEL 1 / 16 IN (BLAST/HBLC library)
 MATERIAL:REGULAR, CORRUGATED METAL, !- Material Name
 Smooth,  !- Roughness
  0.015849600,  !- Thickness (m)
   45.31492    ,   !- Conductivity (W/m-K)
   7833.028    ,   !- Density (kg/m3)
   502.0800    ,   !- Specific Heat (J/kg-K)
  0.2000000    ,   !- Thermal Emittance, was 0.90
  0.2300000    ,   !- Solar Absorptance
  0.2300000    ;   !- Visible Absorptance
! "30-lb felt" -> E3 - 3 / 8 IN FELT AND MEMBRANE (BLAST/HBLC library)
 MATERIAL:REGULAR, FELT, !- Material Name
 Rough,  !- Roughness
  0.0095402403 ,   !- Thickness (m)
  0.1902535    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   1673.600    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7500000    ,   !- Solar Absorptance
  0.7500000    ;   !- Visible Absorptance
! "90-lb rolled roofing" -> ROOFING - ASPHALT ROLL (BLAST/HBLC library)
 MATERIAL:REGULAR, ROLLED ROOFING, !- Material Name
 VeryRough,  !- Roughness
  0.0031699201 ,   !- Thickness (m)
  0.1158817    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   836.8000    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.8000000    ,   !- Solar Absorptance
  0.8000000    ;   !- Visible Absorptance
! one pane of the "Thermopane" -> GLASS - CLEAR SHEET 1 / 8 IN (BLAST/HBLC library),
modified by LANL measurements
 MATERIAL:WindowGlass,GLASS 3 / 16 IN, !- Material Name
   ! (R=.0236,TRANS=.87,VERY SMOOTH,GLASS), from 3mm clear
  SpectralAverage,,  !- Optical Data Type
  0.0047625,  !- Thickness (m)
  0.8306600,  !- Solar Transmittance at Normal Incidence    ! 0.83066, this squared gives
the measured solar transmission of 0.69
```

```
  0.0750000,  !- Solar Reflectance at Normal Incidence: Front Side
  0.0750000,  !- Solar Reflectance at Normal Incidence: Back Side
  0.8980000,  !- Visible Transmittance at Normal Incidence
  0.0810000,  !- Visible Reflectance at Normal Incidence: Front Side
  0.0810000,  !- Visible Reflectance at Normal Incidence: Back Side
  0.0000000,  !- Ir Transmittance at Normal Incidence
  0.8400000,  !- Ir Emittance at Normal Incidence: Front Side
  0.8400000,  !- Ir Emittance at Normal Incidence: Back Side
  0.9000000;  !- Conductivity (W/m-K)
 MATERIAL:WindowGas,AIR SPACE, !- Material Name
  AIR,  !- Gas Type
  0.0127;  !- Gap Width (m) = 1/2 inch
! gap in construction between bricks and surfaces
 MATERIAL:Air,BLOCK AIR SPACE,  !- Material Name
  0.1700000    ;  !- Resistance (m2-K/W)
! Sur-Wall -> CONCRETE - 1 IN MORTAR (BLAST/HBLC library), modified the thickness
 MATERIAL:Regular,Sur-Wall Masonry 1/4 inch,  !- Material Name "a commercial fiber-glass-
filled masonry material"
 Rough,  !- Roughness
  0.00635,         !- Thickness {m}
  0.7200000    ,   !- Conductivity {w/m-K}
   1858.140    ,   !- Density {kg/m3}
   830.0000    ,   !- Specific Heat {J/kg-K}
  0.9000000    ,   !- Thermal Emittance
  0.2000000    ,   !- Solar Absorptance
  0.2000000    ;   !- Visible Absorptance
 MATERIAL:Regular,Selective Surface,  !- Material Name (Berry Solar Products SunSponge
TM)
 Smooth,  !- Roughness
  1.6000000E-03,  !- Thickness (m)           ! from properties of copper
   392.6100,   !- Conductivity (W/m-K)   ! from properties of copper
   8906.260,   !- Density (kg/m3)        ! from properties of copper
   370.0000,   !- Specific Heat (J/kg-K) ! from properties of copper
  0.0700000,   !- Thermal Emittance
  0.9200000,   !- Solar Absorptance
  0.9200000;   !- Visible Absorptance
!*************
! Constructions
!*************
  CONSTRUCTION,Exterior Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      3 1/2 IN STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall Styrofoam, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      STYROFOAM,
      STYROFOAM,
      STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior Mass Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Interior Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Interior Mass Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
```

```
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD;
  CONSTRUCTION,Mass Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Roof, !- Construction Name
      ROLLED ROOFING, !- Outside Layer
      FELT,
      PLYWOOD,
      R-11 INSULATION,
      R-11 INSULATION,
      CORRUGATED METAL,
      STYROFOAM;
  CONSTRUCTION,Double Pane Window, !- Construction Name
      GLASS 3 / 16 IN, !- Outside Layer
      AIR SPACE,
      GLASS 3 / 16 IN;
  CONSTRUCTION, TROMBE WALL IN, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBE WALL OUT, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBESS WALL IN, !- Construction Name
      Selective Surface, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      CONCRETE BLOCK LONG;
  CONSTRUCTION, TROMBESS WALL OUT, !- Construction Name
      CONCRETE BLOCK LONG, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      Selective Surface;
!*************
! Main Zone Geometry
!*************
 ZONE,
  Main Zone, !- Zone Name
  0.000, !- Zone North Axis (relative to Building)
  0.000, !- Zone X Origin [m]
  0.000, !- Zone Y Origin [m]
  0.000, !- Zone Z Origin [m]
  1, !- Zone Type
  1, !- Zone Multiplier
  3.048, !- Zone Ceiling Height [m]
  0.000; !- Zone Volume [m3]
 SURFACE:HEATTRANSFER,
  East Wall, !- Surface Name
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   SunExposed, !- Solar Exposure
   WindExposed, !- Wind Exposure
   0.5, !- VF to Ground
   4, !-Rectangle
   1.578,   0.000,  3.048,
   1.578,   0.000,  0.4927,
   1.578,   2.184,  0.4927,
   1.578,   2.184,  3.048;
 SURFACE:HEATTRANSFER,
  East Mass Wall, !- Surface Name
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Mass Wall, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   SunExposed, !- Solar Exposure
   WindExposed, !- Wind Exposure
   0.5, !- VF to Ground
   4, !-Rectangle
```

```
  1.578,   0.000,  0.4927,
  1.578,   0.000,  0.000,
  1.578,   2.184,  0.000,
  1.578,   2.184,  0.4927;
SURFACE:HEATTRANSFER,
 North Wall, !- Surface Name
 WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
 Exterior Wall, !- Construction Name
 Main Zone, !- Zone Name
 ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
  SunExposed, !- Solar Exposure
  WindExposed, !- Wind Exposure
  0.5, !- VF to Ground
  4, !-Rectangle
  1.578,   2.184,  3.048,
  1.578,   2.184,  1.267,
  0.000,   2.184,  1.267,
  0.000,   2.184,  3.048;
SURFACE:HEATTRANSFER,
 North Mass Wall, !- Surface Name
 WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
 Exterior Mass Wall, !- Construction Name
 Main Zone, !- Zone Name
 ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
  SunExposed, !- Solar Exposure
  WindExposed, !- Wind Exposure
  0.5, !- VF to Ground
  4, !-Rectangle
  1.578,   2.184,  1.267,
  1.578,   2.184,  0.000,
  0.000,   2.184,  0.000,
  0.000,   2.184,  1.267;
SURFACE:HEATTRANSFER,
 West Wall, !- Surface Name
 WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
 Interior Wall, !- Construction Name
 Main Zone, !- Zone Name
 OtherSideCoeff,OSC, !- Exterior Conditions and Target (if applicable)
  NoSun, !- Solar Exposure
  NoWind, !- Wind Exposure
  0.0, !- VF to Ground
  4, !-Rectangle
  0.000,   2.184,  3.048,
  0.000,   2.184,  0.5279,
  0.000,   0.000,  0.5279,
  0.000,   0.000,  3.048;
SURFACE:HEATTRANSFER,
 West Mass Wall, !- Surface Name
 WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
 Interior Mass Wall, !- Construction Name
 Main Zone, !- Zone Name
 OtherSideCoeff,OSC, !- Exterior Conditions and Target (if applicable)
  NoSun, !- Solar Exposure
  NoWind, !- Wind Exposure
  0.0, !- VF to Ground
  4, !-Rectangle
  0.000,   2.184,  0.5279,
  0.000,   2.184,  0.000,
  0.000,   0.000,  0.000,
  0.000,   0.000,  0.5279;
SURFACE:HEATTRANSFER,
 South Wall, !- Surface Name
 WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
 Exterior South Wall, !- Construction Name
 Main Zone, !- Zone Name
 ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
  SunExposed, !- Solar Exposure
  WindExposed, !- Wind Exposure
  0.5, !- VF to Ground
  4, !-Rectangle
  0.000,   0.000,  3.048,
```

```
    0.000,   0.000,  0.000,
    1.578,   0.000,  0.000,
    1.578,   0.000,  3.048;
  SURFACE:HEATTRANSFER,
   Mass Floor, !- Surface Name (This name must be "Mass Floor" so that floor temperature
 from in.dat is used.)
   FLOOR, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
   Mass Floor, !- Construction Name
   Main Zone, !- Zone Name
   ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
    NoSun, !- Solar Exposure
    WindExposed, !- Wind Exposure
    1.0, !- VF to Ground
    4, !-Rectangle
    1.578,   0.000,  0.000,
    0.000,   0.000,  0.000,
    0.000,   2.184,  0.000,
    1.578,   2.184,  0.000;
  SURFACE:HEATTRANSFER,
   Roof, !- Surface Name
   ROOF, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
   Roof, !- Construction Name
   Main Zone, !- Zone Name
   ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
    SunExposed, !- Solar Exposure
    WindExposed, !- Wind Exposure
    0.0, !- VF to Ground
    4, !-Rectangle
    0.000,   2.184,   3.048,
    0.000,   0.000,   3.048,
    1.578,   0.000,   3.048,
    1.578,   2.184,   3.048;
  SURFACE:SHADING:DETACHED:BUILDING,
    Cell 10, !- Surface Name
    , !- Shading transmittance default is always opaque
    4, !- Number of vertices
    2.263,   2.184,  3.556,  ! was 2.948, but it is obviously less than that from the
 picture
    2.263,   2.184,  0.000,
    2.263,   0.000,  0.000,
    2.263,   0.000,  3.556;  ! double check the height
  SURFACE:HEATTRANSFER:SUB,
   Window, !- Subsurface Name
   WINDOW, !- Surface Type
   Double Pane Window, !- Construction Name
   South Wall,,  !- Base Surface Name and Target (if applicable)
   0.5,  !- VF to Ground
   ,  !- Window Shading Control
   ,  !- Frame/Divider Name
   1.0, !- Window Multiplier, only applicable to Windows
   4, !-RectangularDoorWindow
   0.2175,  0.000,   1.915,
   0.2175,  0.000,   0.010,
   1.3605,  0.000,   0.010,
   1.3605,  0.000,   1.915;
  SURFACE:SHADING:DETACHED:BUILDING,
   Overhang,  !- Surface Name
    ,  !- Shading transmittance default is always opaque
    4,  !- Number of vertices
    0.000,   0.000,   3.556,
    0.000, -0.3556,   3.556,
    1.578, -0.3556,   3.556,
    1.578,   0.000,   3.556;
  OTHERSIDECOEFFICIENTS,OSC, !- Other Side Coefficient Name
    1,    !- Combined convective/radiative film coefficient, if 0, surface temp is set
    18.4, !- Constant Temperature [C]
    1,    !- Coefficient modifying the user selected constant temperature
    0,    !- Coefficient modifying the external dry bulb temperature
    0,    !- Coefficient modifying the ground temperature
    0,    !- Coefficient modifying the wind speed term [s/m]
    0;    !- Coefficient modifying the zone air temperature part of the equation
```

```
!*************
! Internal Gains
!*************
LIGHTS,               ! Two 500 W light bulbs controlled thermostatically
    Main Zone,        ! Zone Name
    AlwaysOnSchedule, ! Schedule Name (actually read from in.aux file)
    1000,             ! Design Level {W} (this value is not actually used either)
    0,                ! Return Air Fraction
    0.70,             ! (Fraction Radiant 0.70)   From BLAST defaults for incandescent
bulb
    0.10,             ! (Fraction Visible 0.10)   Fraction Convective = 1 - Radiant -
Visible
    0,                ! Fraction Replaceable
    GeneralLights;    ! LightsEndUseKey
!*************
! Air Loop
!*************
 AIR PRIMARY LOOP,
    Main Air Loop,             ! Primary Air Loop Name
    ,                          ! Controller List
    ,                          ! System Availability Manager List
    0.008750,             ! Primary Air Design Volumetric Flow Rate (m3/s)
    Air Loop Branches,         ! Air Loop Branch List Name
    ,                          ! Air Loop Connector List Name
    Air Loop Inlet Node,       ! Return Air Air Loop Inlet Node
    Main Zone Outlet Node,     ! ZoneEquipGroup Outlet Node
    Zone Equipment Inlet Node, ! Supply Air Path ZoneEquipGroup Inlet Nodes
    Air Loop Outlet Node;      ! Air Loop Outlet Nodes
 BRANCH LIST,
    Air Loop Branches, ! Branch List Name
    Air Loop Branch;   ! Branch Name
 BRANCH,
    Air Loop Branch,         ! Branch Name
    0.008750,           ! Maximum Branch Flow Rate (m3/s)
    OUTSIDE AIR SYSTEM,      ! Component Type
    Outside Air Sys,         ! Component Name
    Air Loop Inlet Node,     ! Component Inlet Node Name
    Outside Air Outlet Node, ! Component Outlet Node Name
    PASSIVE,                 ! Component Branch Control Type
    FAN:SIMPLE:ConstVolume,  ! Component Type
    Ventilation Fan,         ! Component Name
    Outside Air Outlet Node, ! Component Inlet Node Name
    Air Loop Outlet Node,    ! Component Outlet Node Name
    PASSIVE;                 ! Component Branch Control Type
!*************
! Fan Component
!*************
 FAN:SIMPLE:ConstVolume,
    Ventilation Fan,         ! Fan Name
    AlwaysOnSchedule,        ! Fan Schedule
    0.7,                     ! Fan Efficiency
    300.0,                   ! Delta Pressure (N/m2)
    0.008750,           ! Max Vol Flow Rate (m3/s)
    0.9,                     ! Motor Efficiency
    1.0,                     ! Motor In Air Stream Fraction
    Outside Air Outlet Node, ! Inlet Node
    Air Loop Outlet Node;    ! Outlet Node
!*************
! Outside Air Box Component
!*************
 OUTSIDE AIR SYSTEM,
       Outside Air Sys,         ! Name
       Outside Air Controllers, ! Controller List
       Outside Air Equipment,   ! Name of Air Loop Equipment List
       Outside Air Avail List;  ! Name of System Availability Manager List
 CONTROLLER LIST,
       Outside Air Controllers, ! Name
       CONTROLLER:OUTSIDE AIR,  ! Controller Type
       Outside Air Controller;  ! Controller Name
 CONTROLLER:OUTSIDE AIR,
      Outside Air Controller,       ! Name
```

```
      NO ECONOMIZER,                 ! Economizer Choice
      NO RETURN AIR TEMP LIMIT,      ! Return Air Temp Limit Choice
      NO RETURN AIR ENTHALPY LIMIT, ! Return Air Enthalpy Limit Choice
      NO LOCKOUT,                    ! Lockout Choice
      FIXED MINIMUM,                 ! Minimum Limit Choice
      Outside Air Outlet Node,       ! Control Node
      Outside Air Inlet Node,        ! Outside Air Inlet Node
      0.008750,                 ! Minimum Outside Air Flow Rate (m3/s)
      0.008750,                 ! Maximum Outside Air Flow Rate (m3/s)
      ,                              ! Temperature Limit
      ,                              ! Temperature Lower Limit
      ,                              ! Enthalpy Limit
      Exhaust Air Outlet Node,       ! Relief Air Outlet Node
      Air Loop Inlet Node;           ! Return Air Node
 AIR LOOP EQUIPMENT LIST,
      Outside Air Equipment, ! Name
      OUTSIDE AIR MIXER,     ! System Component
      Outside Air Box;       ! Component Name
 OUTSIDE AIR MIXER,
      Outside Air Box,          ! Outside Air Mixer Name
      Outside Air Outlet Node, ! Mixed Air Node (Outlet)
      Outside Air Inlet Node,  ! Outside Air Stream Node (Inlet)
      Exhaust Air Outlet Node, ! Relief Air Stream Node (Outlet)
      Air Loop Inlet Node;     ! Return Air Stream Node (Inlet)
 OUTSIDE AIR INLET NODE LIST,
      Outside Air Inlet Nodes; ! Name
 NODE LIST,
      Outside Air Inlet Nodes, ! Node List Name
      Outside Air Inlet Node;  ! Node Name
 SYSTEM AVAILABILITY MANAGER LIST,
      Outside Air Avail List,               ! Name
      SYSTEM AVAILABILITY MANAGER:SCHEDULED, ! System Availability Manager Type
      Outside Air Avail;                    ! System Availability Manager Name
 SYSTEM AVAILABILITY MANAGER:SCHEDULED,
      Outside Air Avail, ! Name
      AlwaysOnSchedule;  ! Schedule Name
!*************
! Zone Equipment
!*************
 CONTROLLED ZONE EQUIP CONFIGURATION,
    Main Zone,             ! Zone Name
    Main Zone Equipment,   ! Zone Equipment List Name
    Main Zone Inlets,      ! Zone Inlet Nodes
    ,                      ! Zone Exhaust Nodes
    Main Zone Node,        ! Zone Air Node Name
    Main Zone Outlet Node; ! Zone Return Air Node Name
 NODE LIST,
    Main Zone Inlets,     ! Node List Name
    Main Zone Inlet Node; ! Node Name
 ZONE EQUIPMENT LIST,
    Main Zone Equipment,  ! Zone Equipment List Name
    DIRECT AIR,           ! Zone Equipment Type
    Main Zone Direct Air, ! Zone Equipment Name
    1,                    ! Cooling Priority
    1;                    ! Heating Priority
 DIRECT AIR,
    Main Zone Direct Air, ! Direct Air Name
    AlwaysOnSchedule,     ! Schedule Name
    Main Zone Inlet Node, ! Zone Supply Air Node Name
    0.008750;        ! Maximum Air Flow Rate (m3/s)
 ZONE SUPPLY AIR PATH,
    Zone Supply Air Path,      ! Supply Air Path Name
    Zone Equipment Inlet Node, ! Air Path Inlet Node
    ZONE SPLITTER,             ! System Component Type
    Zone Splitter;             ! Component Name
 ZONE SPLITTER,
    Zone Splitter,             ! Splitter Name
    Zone Equipment Inlet Node, ! Inlet Node
    Main Zone Inlet Node;      ! Outlet Node
!*************
! Reporting
```

```
!*************
 DEBUG OUTPUT,0,0; !- 0 is off, 1 is on
 REPORT,Variable Dictionary;
 REPORT,Surfaces,DXF;
 REPORT VARIABLE,*,Outdoor Dry Bulb,Timestep;
 REPORT VARIABLE,*,Outdoor Wet Bulb,Timestep;
 REPORT VARIABLE,*,Outdoor Dew Point,Timestep;
 REPORT VARIABLE,*,Outdoor Enthalpy,Timestep;
 REPORT VARIABLE,*,Outdoor Relative Humidity,Timestep;
 REPORT VARIABLE,*,Sky Temperature,Timestep;
 REPORT VARIABLE,*,Sky Emissivity,Timestep;
 REPORT VARIABLE,*,Outdoor Barometric Pressure,Timestep;
 REPORT VARIABLE,*,Wind Speed,Timestep;
 REPORT VARIABLE,*,Wind Direction,Timestep;
 REPORT VARIABLE,*,Solar Azimuth Angle,Timestep;
 REPORT VARIABLE,*,Solar Altitude Angle,Timestep;
 REPORT VARIABLE,*,Solar Hour Angle,Timestep;
 REPORT VARIABLE,*,Direct Solar,Timestep;
 REPORT VARIABLE,*,Diffuse Solar,Timestep;
 REPORT VARIABLE,*,Auxiliary Heat,Timestep;
 REPORT VARIABLE,*,Adjoining Globe Temperature,Timestep;
 REPORT VARIABLE,*,Mean Radiant Temperature,Timestep;
 REPORT VARIABLE,*,Zone/Sys Air Temp,Timestep;
 REPORT VARIABLE,*,Zone Globe Temperature,Timestep;
 REPORT VARIABLE,*,Opaque Surface Inside Face Conduction,Timestep;
 REPORT VARIABLE,*,Lights-Total Heat Gain,Timestep;
 REPORT VARIABLE,*,Direct Air Sensible Cooling Rate,Timestep;
 REPORT VARIABLE,*,Zone/Sys Sensible Cooling Rate,Timestep;
 REPORT VARIABLE,*,Surface Int Convection Coeff,Timestep;
 REPORT VARIABLE,*,Surface Ext Convection Coeff,Timestep;
 REPORT VARIABLE,*,Surface Inside Temperature,Timestep;
 REPORT VARIABLE,*,Surface Outside Temperature,Timestep;
 REPORT VARIABLE,*,Zone Transmitted Solar,Timestep;
 REPORT VARIABLE,*,Zone Window Heat Gain,Timestep;
 REPORT VARIABLE,*,Zone Window Heat Loss,Timestep;


!*************
! Cell 13 - Reference.idf
!
! Simple enclosure; no windows.
!*************
 VERSION,1.1.0;
 BUILDING,Cell 13 - Reference, !- Building Name
  0, !- Building Azimuth
  Suburbs, !- Building Terrain
  0.04, !- Loads Convergence Tolerance
  0.01, !- Temperature Convergence Tolerance
  FullInteriorAndExterior; !- Solar Distribution
 SURFACEGEOMETRY,UpperLeftCorner,CounterClockWise,WorldCoordinateSystem;
 SHADOWING CALCULATIONS,1; !- recalculate the shadowing every day
 SOLUTION ALGORITHM,CTF; !- Solution Algorithm
 INSIDE CONVECTION ALGORITHM,Detailed; !- Inside Convection Algorithm
 OUTSIDE CONVECTION ALGORITHM,Detailed; !- Outside Convection Algorithm
 TIMESTEP IN HOUR,6;
 LOCATION, LOS ALAMOS NM,     !- Location Name
   35.80000,     !- Latitude {N+ S-}
  -106.3000,     !- Longitude {W- E+}
  -7.000000,     !- TimeZoneNumber {GMT+/-}
   2158.000;     !- Elevation {m}           2158 m   = 7080 ft
 GROUNDTEMPERATURES,13,13,13,13,13,13,13,13,13,13,13,13;  ! Ground temp under slab, not
applicable here
 RUNPERIOD,
  2,             !- Begin Month
  14,            !- Begin Day Of Month
  2,             !- End Month
  22,            !- End Day Of Month
  ;              !- Day Of Week For Start Day
!*************
! Schedules
!*************
```

```
 SCHEDULETYPE,On/Off,0:1,DISCRETE;
 DAYSCHEDULE,AlwaysOnDay,On/Off,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1;
WEEKSCHEDULE,AlwaysOnWeek,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,Alw
aysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay,AlwaysOnDay;
 SCHEDULE,AlwaysOnSchedule,On/Off,AlwaysOnWeek,1,1,12,31;
!*************
! Materials
!*************
! "standard concrete block" -> calculated from LANL report
 MATERIAL:REGULAR, CONCRETE BLOCK,
 MediumRough,  !- Roughness
  0.1428750,   !- Thickness (m)           0.1428750
   1.3848,      !- Conductivity (W/m-K)   1.3848, suggested by Goldstein; nominal 1.731
   2189.06,    !- Density (kg/m3)         2189.06
   510.188,    !- Specific Heat (J/kg-K)  (510.188) -36% from Goldstein, nominal 797.169
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "black painted standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, BLACK PAINTED CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)       bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance   ! with flat black paint
  0.9500000,   !- Solar Absorptance   ! with flat black paint
  0.9500000;   !- Visible Absorptance ! with flat black paint
! "standard concrete block - the long way" -> calculated from LANL report
 MATERIAL:Regular, CONCRETE BLOCK LONG,
 MediumRough,  !- Roughness
  0.3968750,   !- Thickness (m)       bricks oriented the long way ~16 inches
   1.3848,      !- Conductivity (W/m-K)
   2189.06,    !- Density (kg/m3)
   510.188,    !- Specific Heat (J/kg-K)
  0.9000000,   !- Thermal Emittance
  0.8700000,   !- Solar Absorptance   ! 0.87, with dark brown paint
  0.8700000;   !- Visible Absorptance ! 0.87, with dark brown paint
! "5/8-in. plywood" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "5/8-in. plywood, painted white" -> BB46 - 5 / 8 IN PLYWOOD (BLAST/HBLC library)
 MATERIAL:REGULAR, WHITE PAINTED PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.015880080,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.25    ,   !- Solar Absorptance       painted white (unpainted was 0.70)
  0.25    ;   !- Visible Absorptance     painted white (unpainted was 0.70)
! "1/4-in. plywood" -> like above, but thinner
 MATERIAL:REGULAR, THIN PLYWOOD, !- Material Name
 Smooth,  !- Roughness
  0.00635      ,  !- Thickness (m)
  0.1153628    ,   !- Conductivity (W/m-K)
   544.6277    ,   !- Density (kg/m3)
   1213.360    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7000000    ,   !- Solar Absorptance
  0.7000000    ;   !- Visible Absorptance
! "3-1/2-in. insulation, R-11" -> B4 - 3 IN INSULATION (BLAST/HBLC library)
! modified properties to match 3.5 inch fiberglass batt specs found on www
 MATERIAL:REGULAR, R-11 INSULATION, !- Material Name
```

```
 VeryRough,  !- Roughness
  0.0889,          !- Thickness (m)          ! 3.5 in: 0.0889  3 in: 0.076200001
  0.040,   !- Conductivity (W/m-K)   ! www: 0.04592 HBLC: 0.043239430
   84.8    ,   !- Density (kg/m3)            ! www: 84.8    HBLC: 32.03693
   963.7000    ,   !- Specific Heat (J/kg-K) ! www: 963.7   HBLC: 836.8000
  0.9000000    ,   !- Thermal Emittance
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "1-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.025298400,  !- Thickness (m)              ! HBLC: 0.025298400
  0.025,     !- Conductivity (W/m-K)       ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "3.5-in thick extruded styrofoam" -> INS - EXPANDED EXT POLYSTYRENE 1 (BLAST/HBLC
library)
 MATERIAL:REGULAR, 3 1/2 IN STYROFOAM, !- Material Name
 Rough,  !- Roughness
  0.088900,  !- Thickness (m)              ! HBLC: 0.025298400
  0.025,   !- Conductivity (W/m-K)      ! HBLC: 0.035975207     figured from LANL:
0.03050
   28.83323    ,   !- Density (kg/m3)         ! HBLC: 28.83323
   1213.360    ,   !- Specific Heat (J/kg-K)  ! HBLC: 1213.360
  0.8000000    ,   !- Thermal Emittance, was 0.90
  0.5000000    ,   !- Solar Absorptance
  0.5000000    ;   !- Visible Absorptance
! "corrugated metal" -> METAL - GALVANIZED STEEL 1 / 16 IN (BLAST/HBLC library)
 MATERIAL:REGULAR, CORRUGATED METAL, !- Material Name
 Smooth,  !- Roughness
  0.015849600,  !- Thickness (m)
   45.31492    ,   !- Conductivity (W/m-K)
   7833.028    ,   !- Density (kg/m3)
   502.0800    ,   !- Specific Heat (J/kg-K)
  0.2000000    ,   !- Thermal Emittance, was 0.90
  0.2300000    ,   !- Solar Absorptance
  0.2300000    ;   !- Visible Absorptance
! "30-lb felt" -> E3 - 3 / 8 IN FELT AND MEMBRANE (BLAST/HBLC library)
 MATERIAL:REGULAR, FELT, !- Material Name
 Rough,  !- Roughness
  0.0095402403 ,   !- Thickness (m)
  0.1902535    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   1673.600    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.7500000    ,   !- Solar Absorptance
  0.7500000    ;   !- Visible Absorptance
! "90-lb rolled roofing" -> ROOFING - ASPHALT ROLL (BLAST/HBLC library)
 MATERIAL:REGULAR, ROLLED ROOFING, !- Material Name
 VeryRough,  !- Roughness
  0.0031699201 ,   !- Thickness (m)
  0.1158817    ,   !- Conductivity (W/m-K)
   1121.292    ,   !- Density (kg/m3)
   836.8000    ,   !- Specific Heat (J/kg-K)
  0.9000000    ,   !- Thermal Emittance
  0.8000000    ,   !- Solar Absorptance
  0.8000000    ;   !- Visible Absorptance
! one pane of the "Thermopane" -> GLASS - CLEAR SHEET 1 / 8 IN (BLAST/HBLC library),
modified by LANL measurements
 MATERIAL:WindowGlass,GLASS 3 / 16 IN, !- Material Name
   ! (R=.0236,TRANS=.87,VERY SMOOTH,GLASS), from 3mm clear
  SpectralAverage,,  !- Optical Data Type
  0.0047625,  !- Thickness (m)
  0.8306600,  !- Solar Transmittance at Normal Incidence    ! 0.83066, this squared gives
the measured solar transmission of 0.69
  0.0750000,  !- Solar Reflectance at Normal Incidence: Front Side
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  0.0750000,  !- Solar Reflectance at Normal Incidence: Back Side
  0.8980000,  !- Visible Transmittance at Normal Incidence
  0.0810000,  !- Visible Reflectance at Normal Incidence: Front Side
  0.0810000,  !- Visible Reflectance at Normal Incidence: Back Side
  0.0000000,  !- Ir Transmittance at Normal Incidence
  0.8400000,  !- Ir Emittance at Normal Incidence: Front Side
  0.8400000,  !- Ir Emittance at Normal Incidence: Back Side
  0.9000000;  !- Conductivity (W/m-K)
 MATERIAL:WindowGas,AIR SPACE, !- Material Name
  AIR,  !- Gas Type
  0.0127;  !- Gap Width (m) = 1/2 inch
! gap in construction between bricks and surfaces
 MATERIAL:Air,BLOCK AIR SPACE,  !- Material Name
  0.1700000    ;  !- Resistance (m2-K/W)
! Sur-Wall -> CONCRETE - 1 IN MORTAR (BLAST/HBLC library), modified the thickness
 MATERIAL:Regular,Sur-Wall Masonry 1/4 inch,  !- Material Name "a commercial fiber-glass-
filled masonry material"
 Rough,  !- Roughness
  0.00635,         !- Thickness {m}
  0.7200000    ,   !- Conductivity {w/m-K}
   1858.140    ,   !- Density {kg/m3}
   830.0000    ,   !- Specific Heat {J/kg-K}
  0.9000000    ,   !- Thermal Emittance
  0.2000000    ,   !- Solar Absorptance
  0.2000000    ;   !- Visible Absorptance
 MATERIAL:Regular,Selective Surface,  !- Material Name (Berry Solar Products SunSponge
TM)
 Smooth,  !- Roughness
  1.6000000E-03,  !- Thickness (m)           ! from properties of copper
   392.6100,   !- Conductivity (W/m-K)   ! from properties of copper
   8906.260,   !- Density (kg/m3)        ! from properties of copper
   370.0000,   !- Specific Heat (J/kg-K) ! from properties of copper
  0.0700000,   !- Thermal Emittance
  0.9200000,   !- Solar Absorptance
  0.9200000;   !- Visible Absorptance
!*************
! Constructions
!*************
  CONSTRUCTION,Exterior Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      3 1/2 IN STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior South Wall Styrofoam, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      STYROFOAM,
      STYROFOAM,
      STYROFOAM,
      STYROFOAM;
  CONSTRUCTION,Exterior Mass Wall, !- Construction Name
      WHITE PAINTED PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Interior Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM;
  CONSTRUCTION,Interior Mass Wall, !- Construction Name
      STYROFOAM, !- Outside Layer
      R-11 INSULATION,
      STYROFOAM,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
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      R-11 INSULATION,
      PLYWOOD;
  CONSTRUCTION,Mass Floor, !- Construction Name
      THIN PLYWOOD, !- Outside Layer
      R-11 INSULATION,
      R-11 INSULATION,
      PLYWOOD,
      BLOCK AIR SPACE,
      CONCRETE BLOCK;
  CONSTRUCTION,Roof, !- Construction Name
      ROLLED ROOFING, !- Outside Layer
      FELT,
      PLYWOOD,
      R-11 INSULATION,
      R-11 INSULATION,
      CORRUGATED METAL,
      STYROFOAM;
  CONSTRUCTION,Double Pane Window, !- Construction Name
      GLASS 3 / 16 IN, !- Outside Layer
      AIR SPACE,
      GLASS 3 / 16 IN;
  CONSTRUCTION, TROMBE WALL IN, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBE WALL OUT, !- Construction Name
      BLACK PAINTED CONCRETE BLOCK LONG; !- Outside Layer
  CONSTRUCTION, TROMBESS WALL IN, !- Construction Name
      Selective Surface, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      CONCRETE BLOCK LONG;
  CONSTRUCTION, TROMBESS WALL OUT, !- Construction Name
      CONCRETE BLOCK LONG, !- Outside Layer
      Sur-Wall Masonry 1/4 inch,
      Selective Surface;
!*************
! Main Zone Geometry
!*************
 ZONE,
  Main Zone, !- Zone Name
  0.000, !- Zone North Axis (relative to Building)
  0.000, !- Zone X Origin [m]
  0.000, !- Zone Y Origin [m]
  0.000, !- Zone Z Origin [m]
  1, !- Zone Type
  1, !- Zone Multiplier
  3.048, !- Zone Ceiling Height [m]
  0.000; !- Zone Volume [m3]
 SURFACE:HEATTRANSFER,
  East Wall, !- Surface Name   !Zn001:Wall001, ! EAST WALL
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   SunExposed, !- Solar Exposure
   WindExposed, !- Wind Exposure
   0.5, !- VF to Ground
   4, !-Rectangle
   1.578,   0.000,  3.048,
   1.578,   0.000,  0.000,
   1.578,   2.184,  0.000,
   1.578,   2.184,  3.048;
 SURFACE:HEATTRANSFER,
  North Wall, !- Surface Name  ! Zn001:Wall002, ! NORTH WALL
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior Wall, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   SunExposed, !- Solar Exposure
   WindExposed, !- Wind Exposure
   0.5, !- VF to Ground
   4, !-Rectangle
   1.578,   2.184,  3.048,
```

```
   1.578,   2.184,  0.000,
   0.000,   2.184,  0.000,
   0.000,   2.184,  3.048;
 SURFACE:HEATTRANSFER,
  West Wall, !- Surface Name  Zn001:Wall003, ! WEST WALL
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Interior Wall, !- Construction Name
  Main Zone, !- Zone Name
  OtherSideCoeff,OSC, !- Exterior Conditions and Target (if applicable)
   NoSun, !- Solar Exposure
   NoWind, !- Wind Exposure
   0.0, !- VF to Ground
   4, !-Rectangle
   0.000,   2.184,  3.048,
   0.000,   2.184,  0.000,
   0.000,   0.000,  0.000,
   0.000,   0.000,  3.048;
 SURFACE:HEATTRANSFER,
  South Wall, !- Surface Name Zn001:Wall004 ! SOUTH WALL
  WALL, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Exterior South Wall Styrofoam, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   SunExposed, !- Solar Exposure
   WindExposed, !- Wind Exposure
   0.5, !- VF to Ground
   4, !-Rectangle
   0.000,   0.000,  3.048,
   0.000,   0.000,  0.000,
   1.578,   0.000,  0.000,
   1.578,   0.000,  3.048;
 SURFACE:HEATTRANSFER,
  Floor, !- Surface Name
  FLOOR, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Floor, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   NoSun, !- Solar Exposure
   WindExposed, !- Wind Exposure
   1.0, !- VF to Ground
   4, !-Rectangle
   1.578,   0.000,  0.000,
   0.000,   0.000,  0.000,
   0.000,   2.184,  0.000,
   1.578,   2.184,  0.000;
 SURFACE:HEATTRANSFER,
  Roof, !- Surface Name
  ROOF, !- Surface Type (FLOOR | WALL | CEILING | ROOF)
  Roof, !- Construction Name
  Main Zone, !- Zone Name
  ExteriorEnvironment,, !- Exterior Conditions and Target (if applicable)
   SunExposed, !- Solar Exposure
   WindExposed, !- Wind Exposure
   0.0, !- VF to Ground
   4, !-Rectangle
   0.000,   2.184,   3.048,
   0.000,   0.000,   3.048,
   1.578,   0.000,   3.048,
   1.578,   2.184,   3.048;
 SURFACE:SHADING:DETACHED:BUILDING,
  Cell 12, !- Surface Name
   , ! Shading transmittance default is always opaque
   4, !-RectangularOverhang
   2.263,   2.184,  3.556,  ! was 2.948, but it is obviously less than that from the
picture
   2.263,   2.184,  0.000,
   2.263,   0.000,  0.000,
   2.263,   0.000,  3.556;
 SURFACE:SHADING:DETACHED:BUILDING,
  Overhang,  !- Surface Name
   ,  !- Shading transmittance default is always opaque
```

```
   4,  !- Number of vertices
   0.000,   0.000,   3.556,
   0.000, -0.3556,   3.556,
   1.578, -0.3556,   3.556,
   1.578,   0.000,   3.556;
 OTHERSIDECOEFFICIENTS,OSC, !- Other Side Coefficient Name
   1,    !- Combined convective/radiative film coefficient, if 0, surface temp is set
   18.4, !- Constant Temperature [C]
   1,    !- Coefficient modifying the user selected constant temperature
   0,    !- Coefficient modifying the external dry bulb temperature
   0,    !- Coefficient modifying the ground temperature
   0,    !- Coefficient modifying the wind speed term [s/m]
   0;    !- Coefficient modifying the zone air temperature part of the equation
!*************
! Internal Gains
!*************
LIGHTS,               ! Two 500 W light bulbs controlled thermostatically
    Main Zone,        ! Zone Name
    AlwaysOnSchedule, ! Schedule Name (actually read from in.aux file)
    1000,             ! Design Level {W} (this value is not actually used either)
    0,                ! Return Air Fraction
    0.70,             ! (Fraction Radiant 0.70)   From BLAST defaults for incandescent
bulb
    0.10,             ! (Fraction Visible 0.10)   Fraction Convective = 1 - Radiant -
Visible
    0,                ! Fraction Replaceable
    GeneralLights;    ! LightsEndUseKey
!*************
! Air Loop
!*************
 AIR PRIMARY LOOP,
    Main Air Loop,              ! Primary Air Loop Name
    ,                           ! Controller List
    ,                           ! System Availability Manager List
    0.008750,             ! Primary Air Design Volumetric Flow Rate (m3/s)
    Air Loop Branches,          ! Air Loop Branch List Name
    ,                           ! Air Loop Connector List Name
    Air Loop Inlet Node,        ! Return Air Air Loop Inlet Node
    Main Zone Outlet Node,      ! ZoneEquipGroup Outlet Node
    Zone Equipment Inlet Node, ! Supply Air Path ZoneEquipGroup Inlet Nodes
    Air Loop Outlet Node;       ! Air Loop Outlet Nodes
 BRANCH LIST,
    Air Loop Branches, ! Branch List Name
    Air Loop Branch;   ! Branch Name
 BRANCH,
    Air Loop Branch,          ! Branch Name
    0.008750,            ! Maximum Branch Flow Rate (m3/s)
    OUTSIDE AIR SYSTEM,       ! Component Type
    Outside Air Sys,          ! Component Name
    Air Loop Inlet Node,      ! Component Inlet Node Name
    Outside Air Outlet Node, ! Component Outlet Node Name
    PASSIVE,                  ! Component Branch Control Type
    FAN:SIMPLE:ConstVolume,  ! Component Type
    Ventilation Fan,          ! Component Name
    Outside Air Outlet Node, ! Component Inlet Node Name
    Air Loop Outlet Node,     ! Component Outlet Node Name
    PASSIVE;                  ! Component Branch Control Type
!*************
! Fan Component
!*************
 FAN:SIMPLE:ConstVolume,
    Ventilation Fan,          ! Fan Name
    AlwaysOnSchedule,         ! Fan Schedule
    0.7,                      ! Fan Efficiency
    300.0,                    ! Delta Pressure (N/m2)
    0.008750,            ! Max Vol Flow Rate (m3/s)
    0.9,                      ! Motor Efficiency
    1.0,                      ! Motor In Air Stream Fraction
    Outside Air Outlet Node, ! Inlet Node
    Air Loop Outlet Node;     ! Outlet Node
!*************
```

```
! Outside Air Box Component
!*************
 OUTSIDE AIR SYSTEM,
       Outside Air Sys,          ! Name
       Outside Air Controllers, ! Controller List
       Outside Air Equipment,   ! Name of Air Loop Equipment List
       Outside Air Avail List;  ! Name of System Availability Manager List
 CONTROLLER LIST,
       Outside Air Controllers, ! Name
       CONTROLLER:OUTSIDE AIR,  ! Controller Type
       Outside Air Controller;  ! Controller Name
 CONTROLLER:OUTSIDE AIR,
      Outside Air Controller,       ! Name
      NO ECONOMIZER,                ! Economizer Choice
      NO RETURN AIR TEMP LIMIT,     ! Return Air Temp Limit Choice
      NO RETURN AIR ENTHALPY LIMIT, ! Return Air Enthalpy Limit Choice
      NO LOCKOUT,                   ! Lockout Choice
      FIXED MINIMUM,                ! Minimum Limit Choice
      Outside Air Outlet Node,      ! Control Node
      Outside Air Inlet Node,       ! Outside Air Inlet Node
      0.008750,                ! Minimum Outside Air Flow Rate (m3/s)
      0.008750,                ! Maximum Outside Air Flow Rate (m3/s)
      ,                             ! Temperature Limit
      ,                             ! Temperature Lower Limit
      ,                             ! Enthalpy Limit
      Exhaust Air Outlet Node,      ! Relief Air Outlet Node
      Air Loop Inlet Node;          ! Return Air Node
 AIR LOOP EQUIPMENT LIST,
      Outside Air Equipment, ! Name
      OUTSIDE AIR MIXER,     ! System Component
      Outside Air Box;       ! Component Name
 OUTSIDE AIR MIXER,
      Outside Air Box,         ! Outside Air Mixer Name
      Outside Air Outlet Node, ! Mixed Air Node (Outlet)
      Outside Air Inlet Node,  ! Outside Air Stream Node (Inlet)
      Exhaust Air Outlet Node, ! Relief Air Stream Node (Outlet)
      Air Loop Inlet Node;     ! Return Air Stream Node (Inlet)
 OUTSIDE AIR INLET NODE LIST,
      Outside Air Inlet Nodes; ! Name
 NODE LIST,
      Outside Air Inlet Nodes, ! Node List Name
      Outside Air Inlet Node;  ! Node Name
 SYSTEM AVAILABILITY MANAGER LIST,
      Outside Air Avail List,                ! Name
      SYSTEM AVAILABILITY MANAGER:SCHEDULED, ! System Availability Manager Type
      Outside Air Avail;                     ! System Availability Manager Name
 SYSTEM AVAILABILITY MANAGER:SCHEDULED,
      Outside Air Avail, ! Name
      AlwaysOnSchedule;  ! Schedule Name
!*************
! Zone Equipment
!*************
 CONTROLLED ZONE EQUIP CONFIGURATION,
    Main Zone,             ! Zone Name
    Main Zone Equipment,   ! Zone Equipment List Name
    Main Zone Inlets,      ! Zone Inlet Nodes
    ,                      ! Zone Exhaust Nodes
    Main Zone Node,        ! Zone Air Node Name
    Main Zone Outlet Node; ! Zone Return Air Node Name
 NODE LIST,
    Main Zone Inlets,     ! Node List Name
    Main Zone Inlet Node; ! Node Name
 ZONE EQUIPMENT LIST,
    Main Zone Equipment,  ! Zone Equipment List Name
    DIRECT AIR,           ! Zone Equipment Type
    Main Zone Direct Air, ! Zone Equipment Name
    1,                    ! Cooling Priority
    1;                    ! Heating Priority
 DIRECT AIR,
    Main Zone Direct Air, ! Direct Air Name
    AlwaysOnSchedule,     ! Schedule Name
```

```
   Main Zone Inlet Node, ! Zone Supply Air Node Name
   0.008750;        ! Maximum Air Flow Rate (m3/s)
ZONE SUPPLY AIR PATH,
   Zone Supply Air Path,      ! Supply Air Path Name
   Zone Equipment Inlet Node, ! Air Path Inlet Node
   ZONE SPLITTER,             ! System Component Type
   Zone Splitter;             ! Component Name
ZONE SPLITTER,
   Zone Splitter,             ! Splitter Name
   Zone Equipment Inlet Node, ! Inlet Node
   Main Zone Inlet Node;      ! Outlet Node
!*************
! Reporting
!*************
DEBUG OUTPUT,0,0; !- 0 is off, 1 is on
REPORT,Variable Dictionary;
REPORT,Surfaces,DXF;
REPORT VARIABLE,*,Outdoor Dry Bulb,Timestep;
REPORT VARIABLE,*,Solar Azimuth Angle,Timestep;
REPORT VARIABLE,*,Solar Altitude Angle,Timestep;
REPORT VARIABLE,*,Solar Hour Angle,Timestep;
REPORT VARIABLE,*,Sky Temperature,Timestep;
REPORT VARIABLE,*,Outdoor Air Density,Timestep;
REPORT VARIABLE,*,Direct Solar,Timestep;
REPORT VARIABLE,*,Diffuse Solar,Timestep;
REPORT VARIABLE,*,Auxiliary Heat,Timestep;
REPORT VARIABLE,*,Adjoining Globe Temperature,Timestep;
REPORT VARIABLE,*,Mean Radiant Temperature,Timestep;
REPORT VARIABLE,*,Zone/Sys Air Temp,Timestep;
REPORT VARIABLE,*,Zone Globe Temperature,Timestep;
REPORT VARIABLE,*,Opaque Surface Inside Face Conduction,Timestep;
REPORT VARIABLE,*,Lights-Total Heat Gain,Timestep;
REPORT VARIABLE,*,Direct Air Sensible Cooling Rate,Timestep;
REPORT VARIABLE,*,Zone/Sys Sensible Cooling Rate,Timestep;
REPORT VARIABLE,*,Surface Int Convection Coeff,Timestep;
REPORT VARIABLE,*,Surface Ext Convection Coeff,Timestep;
REPORT VARIABLE,*,Surface Inside Temperature,Timestep;
REPORT VARIABLE,*,Surface Outside Temperature,Timestep;
REPORT VARIABLE,*,Surface Ext Solar Incident,Timestep;
```