

4.0 EXPERIMENTAL MEASUREMENTS

The results of the model are validated using experimental measurements. These experiments are designed to be simple and controlled, so that the conditions can be simulated in the model. The transient temperature histories of various locations on the dome are measured in order to compare them to the corresponding temperature results from the model.

4.1 Experimental Procedures

The outer dome of the pyranometer instrument is centered and secured to a 12 in. \times 5 in. \times $\frac{3}{4}$ in. pine wood block using the instrument screws. Three YSI 44031 thermistors are attached to the inside of the dome with a small amount of Silicon Type Z9 heat sink compound. This compound has a high thermal conductivity that minimizes the gradient between the dome and the head of the thermistor. This ensures that the dome temperature is monitored by the thermistor. The thermistors are placed as shown in Figure 4.1 in an effort to monitor the gradient through the dome as a function of time. A fourth thermistor is secured in a small hole drilled into the metal base of the dome to measure its temperature.

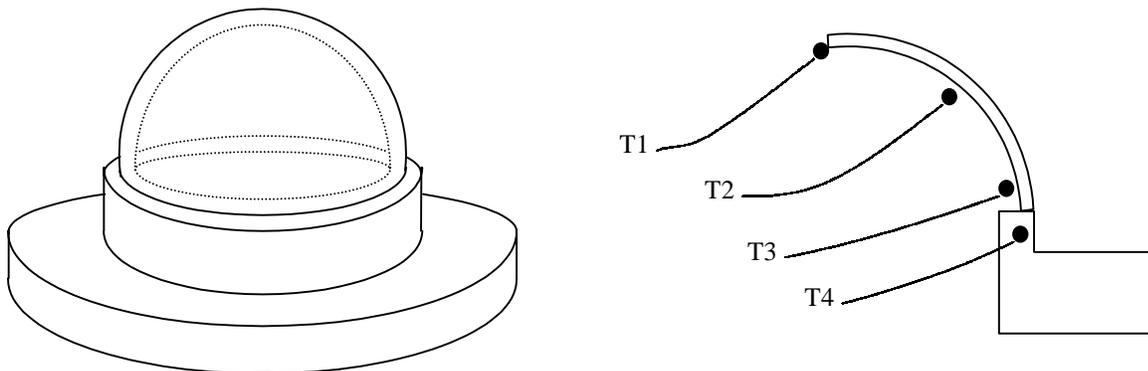


Figure 4.1 Placement of thermistors on the dome glass

A Campbell Scientific Inc. 21x micrologger in conjunction with a PW208 data collection program is used to record data, which was downloaded onto a Dell personal computer. After the experiment, the voltage signal data is loaded into Tecplot, where the voltage signals are converted into thermistor temperatures and the temperatures are plotted as a function of time.

Two types of environmental conditions are simulated using a Sanyo mini-refrigerator. A cooling condition is simulated by taking the dome from a uniform room temperature around 20° C and placing it in the refrigerator, exposing it to a convective and radiative environment of near 0°C. The four-thermistor temperatures are monitored until they approach a steady, uniform value. This typically requires three or four hours. The dome is then left in the refrigerator for several more hours to achieve a uniform temperature. A warming condition is then simulated by removing the dome and exposing it to an environment at room temperature. Again, the temperatures are monitored until they approached a steady, uniform value. The dome is then left to achieve a uniform temperature and the cycle is repeated.

4.2 Sensitivity of Experiment to Environment

During early experiments in which the dome was being cooled in the refrigerator, the non-uniform conditions within the refrigerator were noticed as described in Chapter 3. The freezer compartment in the corner of the refrigerator is a lower temperature radiative heat sink than the other surfaces in the environment. The results of placing the dome in the refrigerator with the thermistors facing the icebox are shown in Figure 4.2. In a uniform environment, the glass cools fastest at the center and slowest near the base. This is because the cooling of the glass base is slowed by thermal conduction from the high thermal mass of the steel rim. The data show that the dome actually cools faster at the 45-deg thermistor than at the center. This is because the 45-deg thermistor is directly facing the freezer compartment, whereas the center is equally exposed to the freezer compartment and the relatively warmer refrigerator walls. In this experimental trial, the thermistor mounted on the edge of the steel rim did not accurately measuring the temperature of the steel. The steel has a much greater thermal capacitance than the glass, and will cool at a much slower rate. Figure 4.2 shows that the thermistor temperature cooled at a faster rate than the base of the glass dome. The thermistor had been exposed to convective heat transfer with the air as well as conductive heat transfer to the steel. In order to improve the experiment, a hole was drilled in the side of the steel rim, and the thermistor head was sealed in the hole with the silicon compound. Subsequent trials revealed that the steel rim thermistor temperature indeed changed slower than the glass thermistor temperatures.

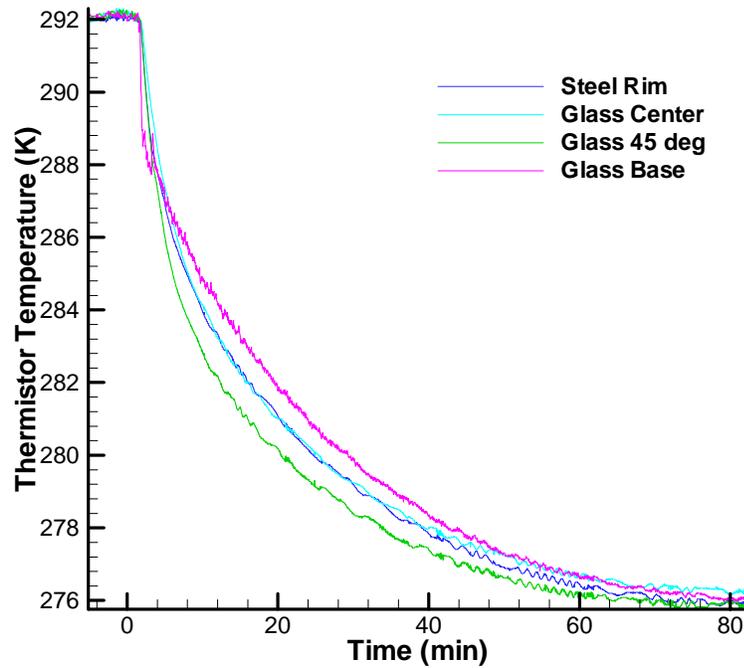


Figure 4.2 Transient cooling data with thermistors facing freezer compartment

The dome model includes the effect of the freezer compartment. However, the actual temperature of the freezer compartment varies as a function of time, and is not known. A method of determining the temperature history from data, as the ambient temperature is determined, is not apparent. Therefore, facing the thermistors away from the freezer compartment allowed for a better comparison with the model because the direct thermal exchange conditions were better known. The experiment was modified to ensure that each trial was performed with the thermistors in this direction. These results are included in Section 4.3.

4.3 Cooling Cases

The cooling experiment was performed on July 2, 1999, and repeated on July 7, 1999. The environmental conditions for these experiments were similar, so that each could be compared with the same model results. The initial condition temperature for the dome is 292.4 K and the ambient temperature appears to be 269.0 K. This is the temperature of the air and the temperature of the refrigerator walls used in the model. The temperature of the freezer compartment in the model is assumed to be 5 deg lower than the ambient temperature, or 264.0K. The data for 7/2/99 and 7/7/99 are shown in Figures 4.3 and 4.4, respectively.

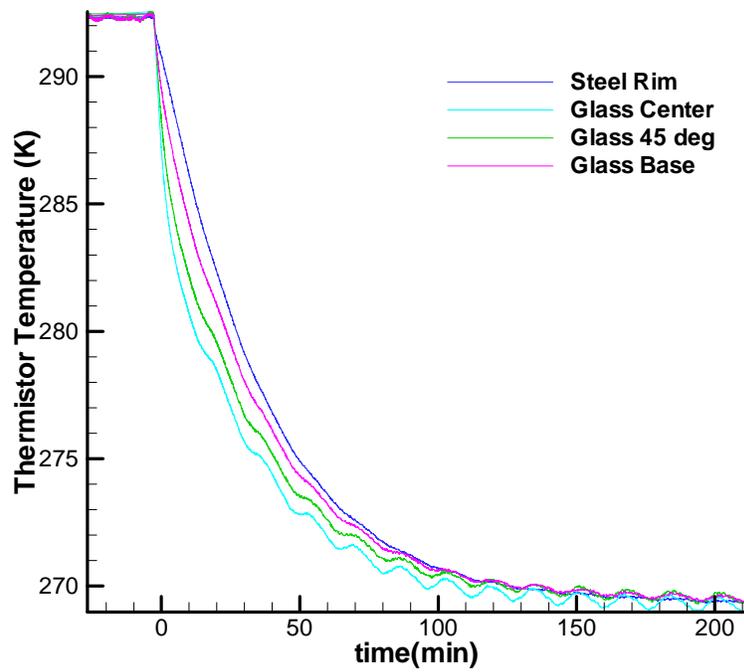


Figure 4.3 Cooling data for 7/2/99

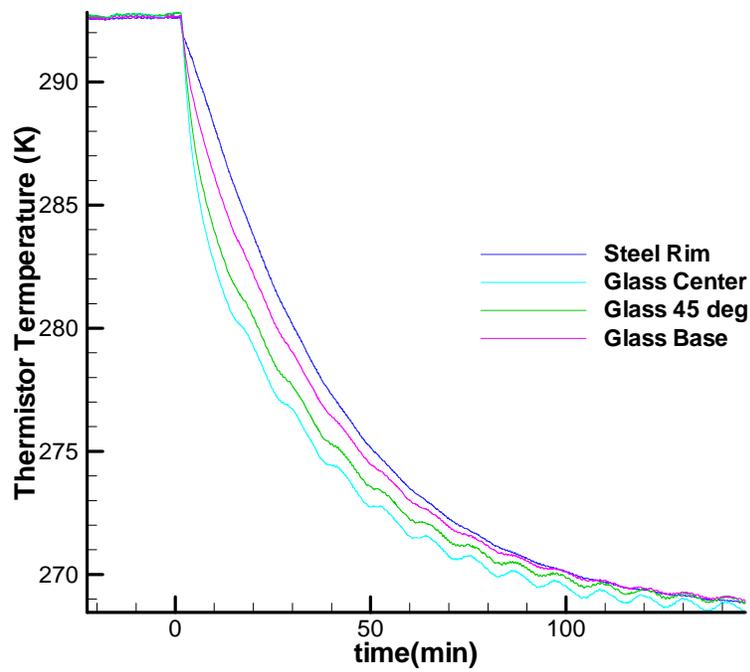


Figure 4.4 Cooling data for 7/7/99

In the cooling temperature data, there is a regular oscillation cycle for each thermistor. This is due to the refrigerator cooling unit cycles. The oscillations are most notable in the glass dome thermistors, because they have a smaller thermal capacitance and, subsequently, a faster response to changes in thermal environment.

4.4 Warming Cases

The warming experiment was performed on June 30, 1999, and repeated on July 6, 1999. The model of the warming experiment consists of a uniform environment, so that the results are axisymmetric. However, the environmental conditions varied between experiments, so that each experiment was modeled using its respective environmental conditions. The data for 6/30/99 are shown in Figure 4.5. The initial condition temperature for the dome is 272.8 K and the sink temperature for radiation and convection appears to be 292.4 K. The data for 7/6/99 are shown in Figure 4.6. For this experiment, the dome is initially at 268.5 K and the sink temperature appears to be 296.0 K.

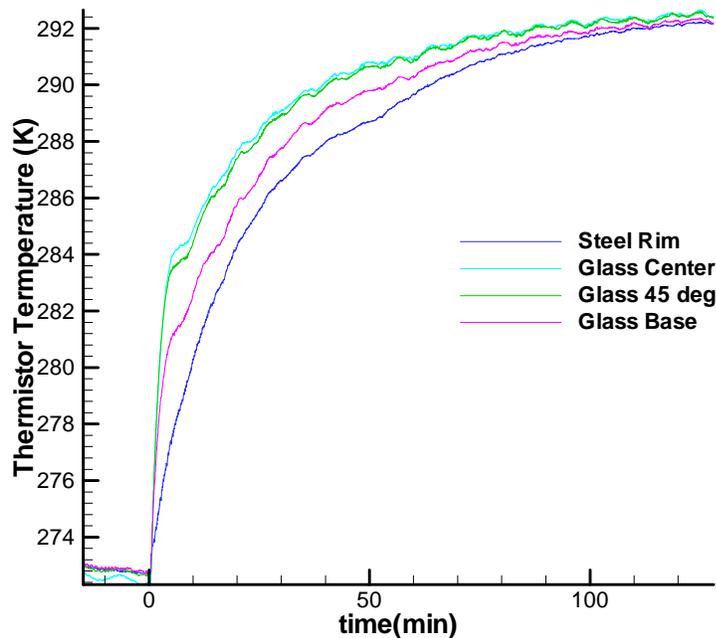


Figure 4.5 Warming data for 6/30/99

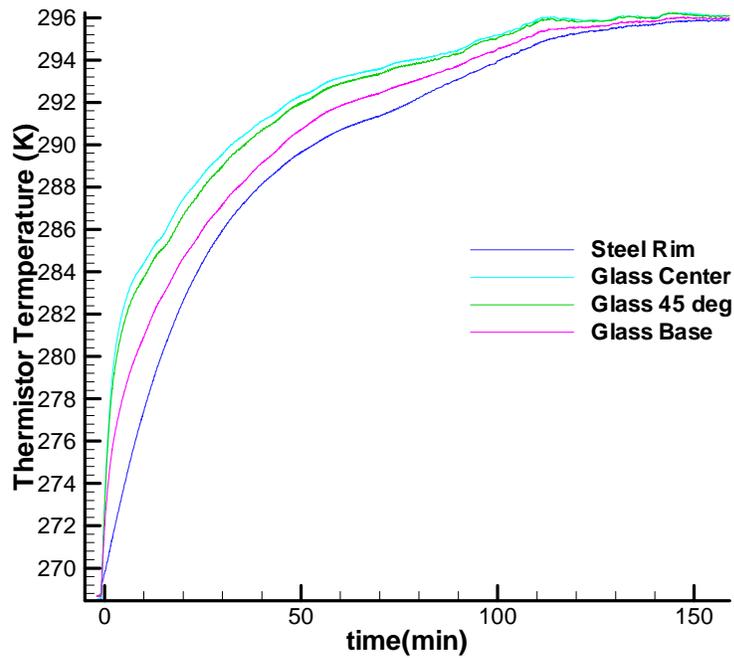


Figure 4.6 Warming data for 7/6/99

In the warming temperature data, there appear oscillations similar to those in the cooling data, but less regular. These correspond to the air conditioning unit activating and deactivating in the trailer where the experiments were performed. Since this cycle time is subject to variation, this appears as cycle irregularity in the data.

The data obtained with these experiments were used to validate the models ability to simulate the thermal exchanges on the dome and produce accurate temperature results. This validation is the subject of Chapter 5.