7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Finite Element Modeling of the Pyranometer

The finite element model of the pyranometer domes has offered insight into the thermal exchanges within the instrument. The model is able to describe the thermal state of the instrument components with detail and accuracy. This is a useful tool in understanding the thermal offset present in the measurements. The model is used to determine the temperature spread on the inside surface of the filter dome under various environmental conditions. The resulting thermal radiation to the sensor from the dome is then determined. The instrument measurement, resulting from the sum of the incident shortwave irradiance and this parasitic irradiance, may then be corrected accordingly.

The steady-state model has demonstrated that the attempt to reduce the thermal offset using ventilation of the dome is effective, but limited. The convective exchange with ambient air, a linear function of T_{air}-T_{dome}, cannot completely compensate for the radiative exchange to the nighttime sky, a linear function of T_{sky}^4-T_{dome}^4. Here T_{dome} represents the effective dome temperature whose value takes into account the temperature distribution on the filter dome.

The transient model was able to reproduce the experimental results, verifying the accuracy of the model. The time history of the dome model can be used to analyze the effect of thermal shock on instrument measurements.

The results of these models produce possible temperature distributions that may be present on the dome at a given time. The analysis of a temperature distribution produces an ideal location to measure a representative temperature that may be used in a correction algorithm to account for the thermal irradiances from the dome.

7.2 Modifying the Pyranometer and Correcting Measurements

The team at NASA Langley, led by Dr. Martial Haeffelin, is currently working on modifying the pyranometer instrument so that the representative temperature is monitored. They are experimentally determining the ability to correct measurements with this method. The Eppley PSP has been modified for this experiment by securing a thermistor to the inside surface of the dome at the 40-deg location, the appropriate location determined in Section 6.4. Another thermistor is located on the instrument heat sink. These temperatures are then used in Equation 2.4 to obtain a corrected measurement.

7.3 Recommendations for Model Development

Important discoveries have been made with the model developed in this effort. However, further insight into measurement error in the pyranometer will be gained by expanding the model. In addition to thermal exchanges with the inner dome, the sensor is vulnerable to other sources of error that originate from sources other than the dome. The pyranometer is designed to minimize the effects of these errors, but as more accuracy of measurement is sought, these effects should be examined. The inner dome, for instance, is not exposed to a uniform environment; rather it exchanges radiation with the outer dome. This may lead to different temperature distributions on the inner dome than those produced by the current model. The sensor surface is subject to conduction through its mounting surface, which conducts through the instrument body. The thermopile output actually consists of an ambient-temperature-dependent relation to temperature. The dependence may be a source of error, especially when operated in extreme conditions.

Solar irradiance of the instrument should be included in further development of the model. The thermal behavior in solar radiation describes the true operating conditions. A radiation model being developed in parallel with the conduction model determines the interaction of the instrument with solar radiation. Because the absorbed radiation model is temperature dependent, an analysis cycle, shown in Figure 7.1, must be established between the radiation and conduction model. An initial temperature distribution on the instrument is assumed, and the solar irradiance distribution incident to the instrument is defined by the radiation model. The resulting absorbed fluxes are calculated for the given temperature distribution. These fluxes are distributed on the model as heat sources and a revised temperature distribution is calculated. The iteration begins as this temperature distribution serves as the input for the radiation model. The cycle continues until the temperature distribution converges to a solution.

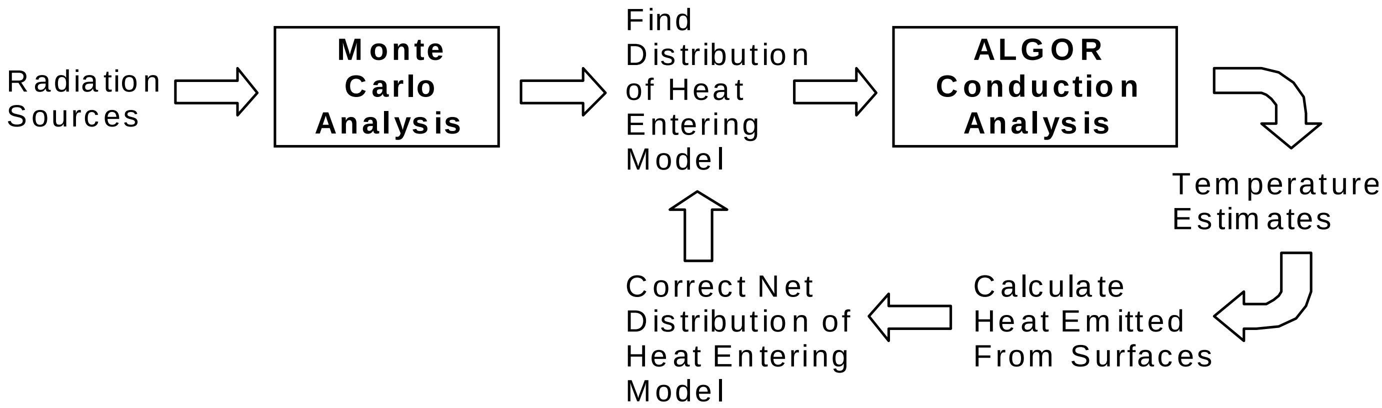

Figure 7.1 Coupling a radiation model with the finite element model

7.4 Incorporation of a Monte-Carlo-Ray-Trace model

Monte-Carlo-Ray-Trace (MCRT) is a method for statistically predicting radiative exchanges among surface and volume elements. For the pyranometer, an MCRT model could predict the amount of radiation absorbed on the outer surfaces of the instrument and within the volume of the filter domes. The radiation model can also determine the radiative interaction between surfaces and volume elements within the instrument. For instance, the radiation exchange between the two domes can be determined by finding the amounts of radiation leaving the volume elements of one that arrive at those defining the other. The nodes in the finite element model may then be radiatively coupled to each other using this information. This way the temperature-dependent radiative exchanges within the instrument can be evaluated along with the conduction.

A complete model of the pyranometer that includes conductive and radiative exchanges within the instrument and with the surroundings will more accurately simulate the operating conditions of the instrument. The sensitivity of measurements to various sources of error can then be determined, and an appropriate correction method may then be applied to future measurements with the pyranometer.