

Blackbody Cavity for Calibrations at 200 to 273 K

Care must be taken to ensure high emissivity to minimize error.

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A laboratory blackbody cavity has been designed and built for calibrating infrared radiometers used to measure radiant temperatures in the range from about 200 to about 273 K. In this below-room-temperature range, scattering of background infrared radiation from room-temperature surfaces could, potentially, contribute significantly to the spectral radiance of the blackbody cavity, thereby contributing a significant error to the radiant temperature used as the calibration value. The spectral radiance error at wavelength λ is given by $[1-\epsilon(\lambda)][B(T_c, \lambda) + B(T_a, \lambda)]$ (1), where $\epsilon(\lambda)$ is the effective spectral emissivity of the cavity, $B(T, \lambda)$ is the ideal spectral radiance of a body at absolute temperature T according to Planck's radiation law, T_c is the temperature in the cavity, and T_a is the ambient temperature. Examining expression (1) shows that making $\epsilon(\lambda)$ as close as possible to unity, one can minimize the spectral-radiance error and the associated radiant-temperature error. For example, (see Figure 1) it has been calculated that to obtain a radiant-temperature error of 1 K or less at a cavity temperature of 200 K, ambient temperature of 300 K, and wavelength of 6 μm , one have $\epsilon(\lambda) > 0.999$. A 1 K radiant-temperature error is more than sufficient for atmospheric and cloud studies which is a common application of infrared radiometers.

The present blackbody cavity is of an established type in which multiple reflections from a combination of conical and cylindrical black-coated walls (see Figure 2) are exploited to obtain an effective emissivity greater than the emissivity value of the coating material on a flat exposed surface. The coating material in this case is a flat black paint that has an emissivity of approximately of 0.91 in the thermal spectral range and was selected over other, higher-emissivity materials because of its ability to withstand thermal cycling. We found many black coatings cracked and flaked after thermal cycling due to differences in the coefficient of expansion differences. On the basis of theoretical calculations, the effective emissivity is expected to approach 0.999.

The cylindrical/conical shell enclosing the cavity is machined from copper, which is chosen for its high thermal conductivity. In use, the shell is oriented vertically, open end facing up, and inserted in a Dewar flask filled with isopropyl alcohol/dry-ice slush. A flange at the open end of the shell is supported by a thermally insulating ring on the lip of the Dewar flask. The slush cools the shell (and thus the black-body cavity) to the desired temperature. Typically, the slush starts at a temperature of about 194 K. The slush is stirred and warmed by bubbling dry air or nitrogen through it, thereby gradually increasing the temperature through the aforementioned calibration range during an interval of several hours. The temperature of the slush is monitored by use of a precise thermocouple probe. A comparison with a independently calibrated commercial radiometer with a thermocouple demonstrated less than a 1 K difference between a thermocouple in the slush and the radiometers output. The flow of dry air also acts as a purge to prevent airborne water vapor from frosting the conical and cylindrical cavity surfaces.

This work was done by Dane Howell, Robert Ryan, Jim Ryan, Dane Howell, Doug Henderson and Larry Clayton at the Stennis Space Center.

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figure captions:

(1 column)

Figure 1. The **Error in the Radiant Temperature** as a function of wavelength was calculated for three different emissivity values for a cavity temperature of 200 K and ambient temperature of 300 K.

(1 column)

Figure 2. The **Black-Body Cavity** has a shape and size chosen as a compromise among maximizing the number of internal reflections, maximizing effective emissivity out to an acceptably large radius, and keeping the cone short enough to fit in a Dewar flask as shown.

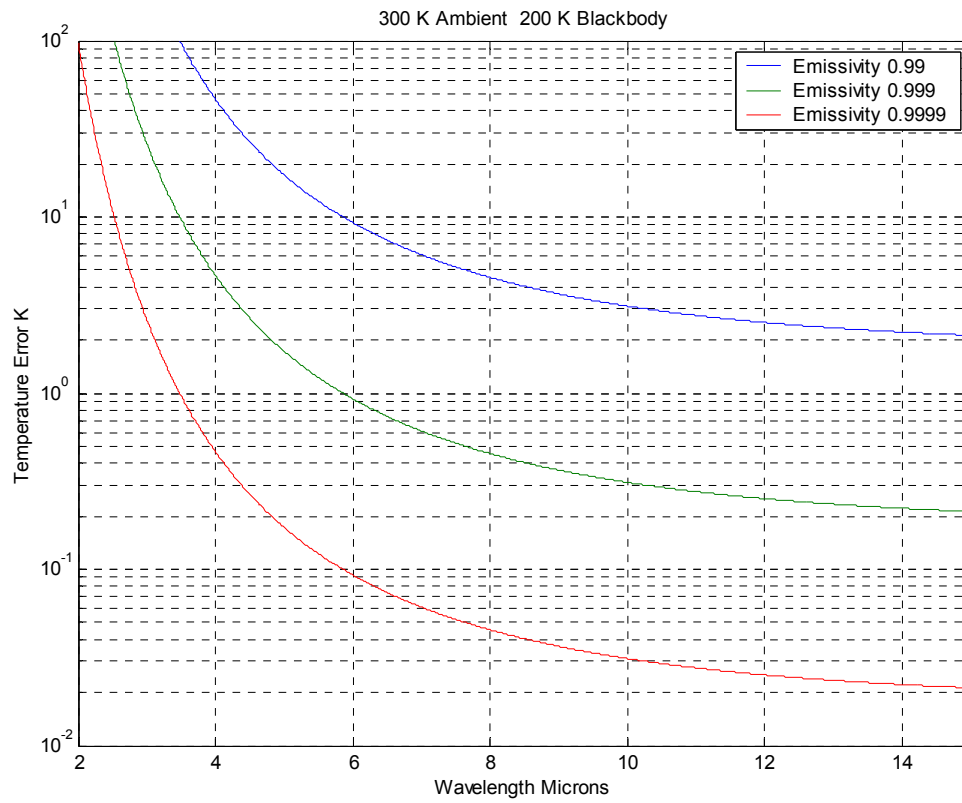


Figure 1

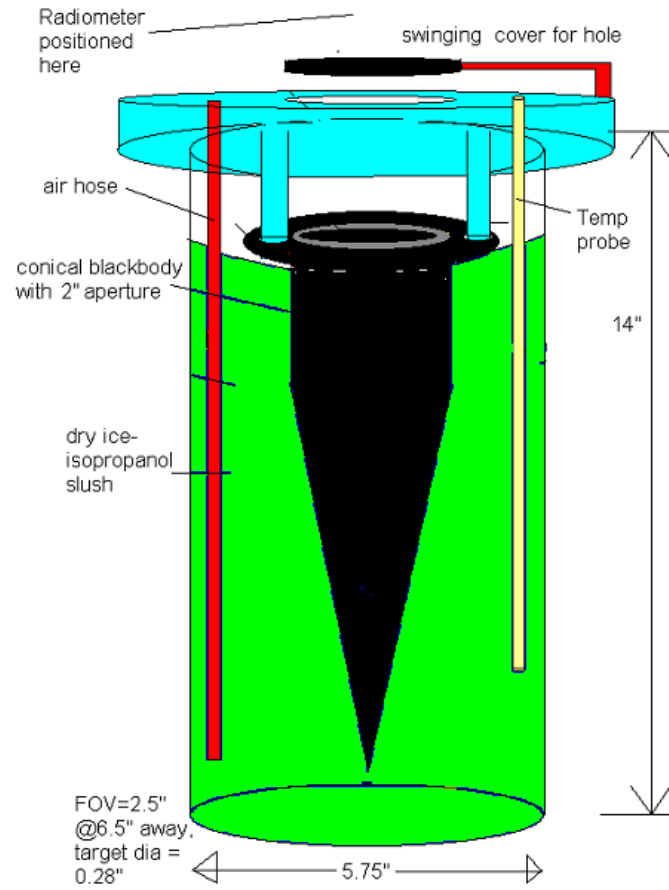


Figure 2