LABORATORY MEASUREMENT OF THE DEPENDENCE OF PARTICLE SIZE ON THERMAL CONDUCTIVITY UNDER MARTIAN CONDITIONS *M.A. Presley and P.R. Christensen, Dept. of Geology, Arizona State University, Tempe AZ 85287*

Thermal inertia determinations from the Mariner 9 Infrared Radiometer and the Viking Infrared Thermal Mapper data have been used to approximate the mean particle diameter of surficial units on Mars [1,2]. Several studies [e.g. 5,6,7] have used this approximation in order to characterize surficial units and infer their nature and possible origin. This is possible because previous measurements of the thermal conductivity of granular materials have shown that particle size has a significant effect under martian atmospheric conditions [e.g. 6,7,8]. The transfer of thermal energy due to collisions of gas molecules is the predominant mechanism of thermal conductivity in porous systems for gas pressures above about 0.01 torr. At martian atmospheric pressures the mean free path of the gas molecules becomes greater than the interparticle spacing. Gas particles are then more likely to collide with the solid particles than they are to each other. The dimensions of the interparticle spacing, which are deterinined by particle size, shape and packing, thus controls how fast heat will flow through a material.

The derived one-to-one correspondence of thermal inertia to mean particle diameter implies a certain homogeneity in the original materials. Yet the samples [1] were characterized by fairly wide ranges of particle sizes with no information about the possible distribution within those size ranges. Interpretation of thermal inertia data is further limited by the lack of data on other effects on the interparticle spacing relative to particle size, such as bimodal or polymodal mixtures of grain sizes, particle shape and formation of salt cements between grains.

To address these questions and to provide a more comprehensive set of data of thermal conductivities vs. particle sizes an apparatus has been constructed to provide a means of measuring the thermal conductivity of particulate samples. The line heat source technique is employed since it is relatively easy to use, measurements can be made within a few minutes after equilibration of the system has been reached, and it is more accurate than other methods [8]. The theory behind this technique is discussed in detail in Carslaw and Jaeger [9]. Blackwell [10,11] also addresses the experimental errors inherent to this method. This technique employs a long, thin linear heat source, whose length to diameter ratio should be greater than 30, imbedded in the sample. The change in temperature due to the heat source over a time period t_1 to t_2 can be approximated by:

$$T_2 - T_1 = \frac{q}{4\pi\kappa} \ln \frac{t_2}{t_1}$$

where q is the heat flux per unit length of the source and κ is the thermal conductivity [8,11]. A plot of temperature vs. the natural log of time will thus yield a straight line with a slope of $q/4\pi\kappa$.

The experimental apparatus is set up similar to that of Cremers [12,13]. A sample holder patterned after Cremers [12] was machined out of Teflon and holds approximately 50 g of sample. The linear heat source is a 5 cm length of 36 AWG (0.005 inches) platinum wire powered by a constant current power supply. A butt-welded 36 AWG copper-constantan thermocouple placed, in parallel, 2.0 mm from the heating wire is used to measure, with a precision of ±0.5°C, the temperature change within the sample due to the linear heat source. The sample holder sits in a hollow-walled copper sample chamber. This chamber can be chilled with a flow of liquid nitrogen through the walls and lid of the chamber. The temperature is regulated and maintained by controlling the rate of flow of the liquid nitrogen by exposing the liquid nitrogen dewar to a constant back pressure. Two 35-liter dewars are connected to the sytem by a T-valve. In this way temperatures ranging from -100° to 25°C may be maintained indefinitely by

alternating the dewars. This increases the rate of data collection by allowing measurements at several different pressures and temperatures with a minimum amount of lag time between measurements. After an initial stabilization period of 24-48 hours, shifts to different pressures could be acheived and stabilized within a couple of hours and shifts to different temperatures could be acheived and stabilized within 3-6 hours. The sample chamber sits within a vacuum bell jar. Once the air is evacuated, the system is back filled with CO_2 and the pressure is regulated and maintained to within ±0.1 torr by a dynamic pressure regulating system which can instantly compensate for changes in pressure due to adsorption or degassing by the sample or due to temperature changes.

In order to concentrate on the dependence of the thermal conductivity on particle size, initial runs will use spherical glass beads that are precision sieved into relatively small size ranges and thoroughly washed. All size ranges used have less than a 10 μm spread, except for the 500-520 μm sample, and several samples have a spread of 5 μm or less. The total range of sizes to be examined is 10 μm to 500 μm. Later runs will examine the affect of shape by using angular sand grains, sieved and washed to the same size ranges as the glass beads, and platy clays.

The affects of the heterogeneity of samples will be examined by considering two-component systems, varying the abundance of the fine component from 0 to 100% by 10%. In these experiments the 100 μm material will be the course fraction and the 10 μm material will be the fine fraction. Runs will also be made on real eolian and fluvial sediments to determine the effects of natural distributions of particle sizes and to determine how these compare to the controlled set of experiments.

The results of this study will include 1) a matrix of thermal conductivity measurements that covers a full range of expected martian particle sizes, pressures and temperatures, 2) direct SEM measurements of micro-scale textures of selected samples, which will allow the results to be quantified in terms of physical properties of the sample such as particle size, particle shape, porosity and grain to grain contacts, and 3) thermal conductivity measurements of a suite of artificial and natural mixtures of particle sizes will be conducted and used to develop a more sophisticated model to aid in the interpretation of remote sensing observations of Mars.

References

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