THERMAL CONDUCTIVITY OF APOLLO 16 LUNAR FINES

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Thermophysical property measurements for samples returned by the earlier Apollo missions are in the literature and have been summarized by Birkebak (1) and Cremers (2). The measurements reported in the present paper are for the Apollo 16 fines only. If one is concerned with energy transfer on the surface of the moon, either in the surface layer or in systems which might be used there, then the rocks are not of much importance. The moon, at least in the regions so far visited, is covered to a depth of several meters or more with the fine material. Rocks and boulders are present but only randomly and relatively infrequently. Consequently, they represent more or less of a perturbation on the fine particulate nature of the surface layer and so energy transfer there depends for the most part on the properties of the fines.

This paper presents the thermal conductivity as a function of temperature over the approximate range of lunar diurnal temperatures. The density of 1500 kg/m^3 which is used corresponds approximately to that reported for the Apollo 16 core-tube samples and so it should be close to that at the mission site itself. There is some doubt as to whether or not these core-tube samples represent the actual site conditions. Recent temperature measurements at the Apollo 16 site can be explained only if densities there are considerably greater as if the material were behaving like a semi-rock. This question is not likely to be resolved until a new series of flights to the moon is carried out.

The thermal conductivity measured for Apollo 16 lunar fines sample 68501, as catalogued by the Lunar Receiving Laboratory at the Manned Spacecraft Center, NASA, Houston, is shown in Figure 1. The individual data points are indicated by the circles and curve of the form

$$k = A + BT^3 \qquad (1)$$

is given by the solid line. This expression is derived from elementary theory and essentially gives the sum of conductive plus radiative contubutions to the effective thermal conductivity. A and B are determined by a least-squares analysis of the data shown in Figure 1. These are: $A = 0.484 \times 10^{-3}$ W/m-K and $B = 0.111 \times 10^{-10}$ W/m-K^4. A similar

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curve for Apollo 15 sample 15031 at the same density is shown for comparison. The two samples appear to be similar in their conducting capabilities which indicates a rather general similarity in particle size and shape distribution. In contrast, the Apollo 11, Apollo 12, Apollo 14 and terrestrial basalt samples have effective conductivities which are about twice as great in magnitude and have roughly the same temperature dependence. As all the samples have basically the composition of what are considered silicate rocks, the differences from one to the other can be ascribed to particulate effects rather than compositional effects. That is, the effects of particle size and shape distribution should be overriding. This is because of the influence these parameters have on solid conduction path and resistance to radiative heat flow, either from scattering or emission.

The thermal diffusivity is obtained from the relationship $\alpha = k/\rho c$. This has been calculated for a density of 1500 kg/m^3 by using the thermal conductivity from the last section along with the specific heat data of Hemmingway and Robie (4). These latter data were taken for Apollo 16 sample 60601 which is a sample from the same landing site but different location there. There are no such data available for the sample 68501 and the authors were not authorized to make such measurements. However, specific heat data for all silicate rocks are so similar that there should be only little inaccuracy from this substitution.

The diffusivity was calculated at 20K intervals corresponding to the temperatures used in (4). The conductivity used in the calculation was determined by using Equation 1. The results are also plotted in Figure 1 and the curve shown is a fifth order polynomial fitted through the calculated values. That is,

$$\alpha = a + bT + cT^2 + dT^3 + eT^4 + fT^5 \qquad (2)$$

Here $a = 0.497 \times 10^{-8}\ m^2/s$, $b = 0.759 \times 10^{-10}\ m^2/s - K$, $c = 0.555 \times 10^{-12}\ m^2/s - K^2$, $d = 0.209 \times 10^{-14}\ m^2/s - K^3$, $e = 0.397 \times 10^{-17}\ m^2/s - K^4$ and $f = -0.301 \times 10^{-20}\ m^2/s - K^5$.

The fifth degree polynomial was chosen simply because it represented the data better than other polynomials.

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(3) "Apollo 16 Preliminary Science Report", NASA Spec. Publ. NASA SP-315 (1973).

(4) Hemingway, B.S. and Robie, R.A.: "Lunar Science IV", J.W. Chamberlain and C. Watkins, ed., Lunar Science Inst., Houston (1973).

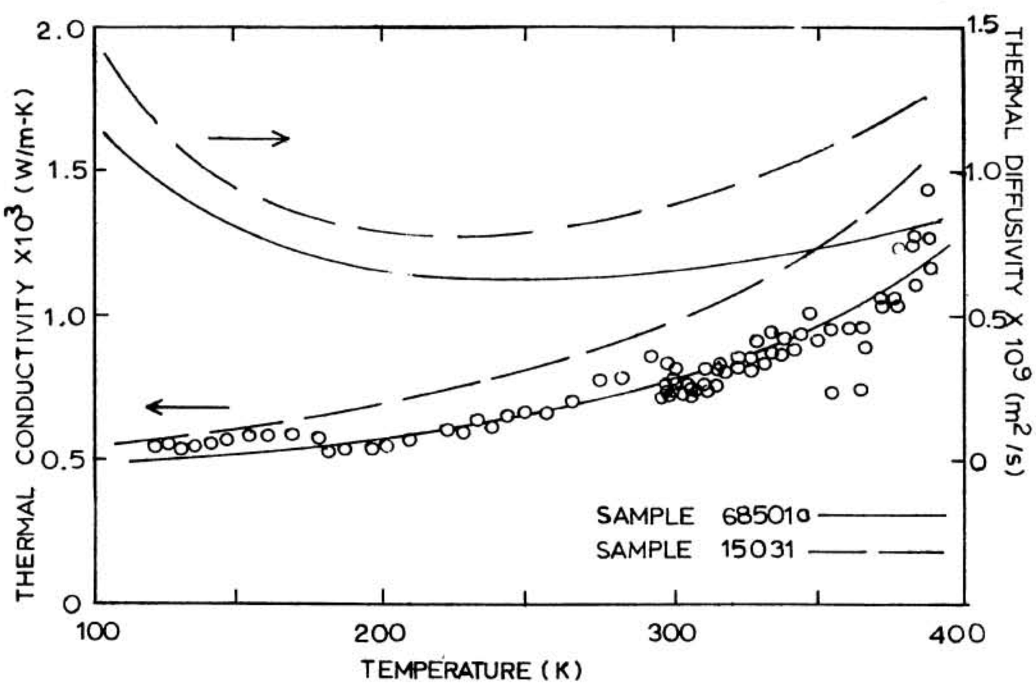

Figure 1 Thermal Conductivity and Thermal Diffusivity of Lunar Fines