MEASUREMENT OF THE LUNAR REGOLITH THERMAL CONDUCTIVITY IN THE LUNAR-A MISSION by K.Horai, Meteorological Research Institute, A. Fujimura, S.Tanaka and H.Mizutani, Institute of Space and Astronautical Science

In the Lunar-A Mission scheduled in 1996, measurements of lunar heat flow by means of lunar penetrator are planned. The penetrator is a cylinder of about 1m long and 12cm in diameter with one of its ends tapered like a cannonball in order to facilitate the entrance as it hits the lunar surface. It is released from lunar orbiter, decelerated during the fall to lessen the impetus of impact, and, on hitting the lunar surface, penetrated into the lunar regolith to the depths of 1 to 2m.

The determination of heat flow requires both the rate of temperature increase with depth and the thermal conductivity to be known precisely. The former can be estimated from the measurement of lunar regolith temperature made by the sensors attached to the penetrator. The measured temperatures need to be corrected for the distortion of the temperature field that should inevitably be brought about with the thermally more conductive penetrator that was embedded in the thermally less conductive lunar regolith. An extensive numerical simulation is under way to formalize the procedure of correction.

As for the measurement of thermal conductivity, it is to be carried out with a device installed in the penetrator. The measurement principle is based on the thermal response of a composite material to the interfacial heating. Heat a small circular portion of the penetrator surface at a known rate and measure the temperature at the center of the area. As the penetrator is contacted with the lunar regolith, the heat dissipates through both substances composing the lunar regolith and the penetrator itself. The rise of temperature at the heating area is, therefore, indicative of the thermal properties of the lunar regolith and the penetrator. As the thermal properties of the material composing the penetrator are known, those of the lunar regolith can be deduced from the temperature data.

Let the thermal conductivity, the density, the specific heat and the thermal diffusivity of the penetrator be, respectively, $k_1$, $\rho_1$, $c_1$ and $\kappa_1 = k_1/\rho_1 c_1$ that are distinct from the corresponding $k_2$, $\rho_2$, $c_2$ and $\kappa_2 = k_2/\rho_2 c_2$ of the lunar regolith that is separeted from the penetrator by a plane boundary. Suppose a circular disk of radius <u>a</u> placed on the boundary starts emitting heat from time $t = 0$ at a constant rate Q per unit time per unit area of the heating disk. Then, the temperature T rising with time t at the center of the disk is a function of the thermal properties of the materials on both sides of the boundary. The rate of temperature increase immediately after the start of heating is

$$T/\sqrt{t} \simeq (2Q/\sqrt{\pi})/(\sqrt{k_1 \rho_1 c_1} + \sqrt{k_2 \rho_2 c_2})$$

which provides a basis for estimating $\sqrt{k_2 \rho_2 c_2}$ of the lunar regolith from the known thermal properties ($k_1$, $\rho_1$, $c_1$) of the penetrator. Further fitting of the theoretical curve to the temperature record gives an estimate of $\kappa_2 = k_2/\rho_2 c_2$ that makes it possible to separate $k_2$ from $\rho_2 c_2$.

Figure 1 illustrates the unit to be mounted on the penetrator. A copper disk of 4mm in diameter and 0.3mm in thickness is underlain by a strain gauge of the same diameter and 0.1mm thick that serves as a heating element. It contains a thin wire of $120\Omega$ that is folded into a small area of about 1mm wide and is sandwiched between thin insulating films. The heater is energized with a dc current of 1.5V and the rise of temperature is measures by a thermocouple placed underneath the middle of the heater.

Feasibility of the method was demonstrated by test experiments. A group of non-metallic solids of known thermal properties were selected as samples. They were contacted with a model heater and temperature data were taken under simulated conditions. Analysis of the data showed that the measured rate of temperature increase with time varies systematically with the sample's $\sqrt{k\rho c}$ as shown in Figure 2. For $\log_{10}\sqrt{k\rho c} = -2.50$ of the lunar regolith, a difference of factor 2 in the thermal conductivity would result in a change of $0.001\ mV/\sqrt{u}$ which is within the resolvable range of the measurement. Refining the arrangement of the heater and the temperature sensor, the method is expected to yield a result that is quantitatively satisfactory as well.

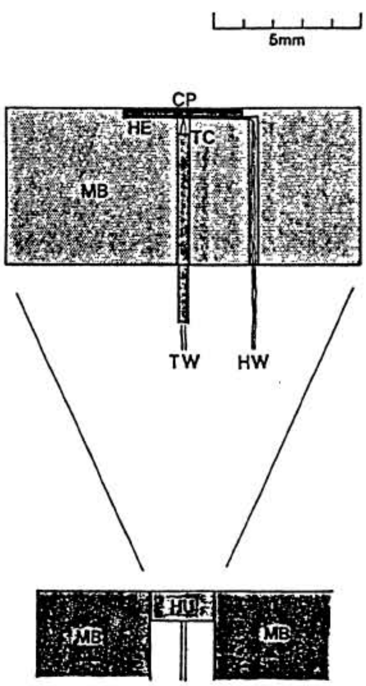


Figure 1. Heating unit to be mounted on the Lunar-A Mission penetrator for the measurement of lunar regolith thermal conductivity.

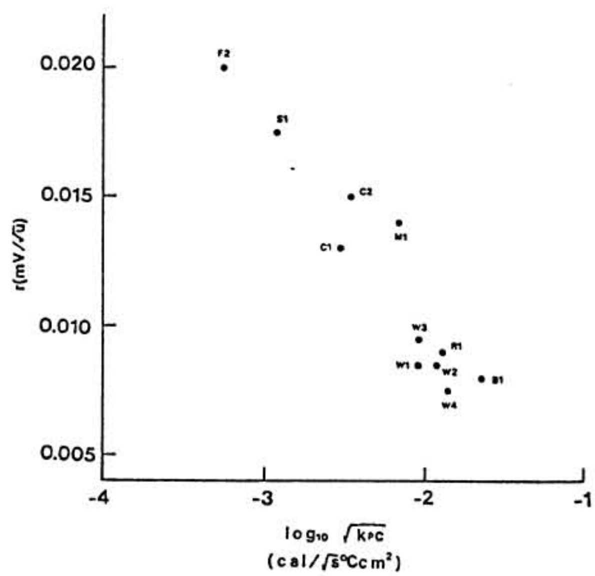


Figure 2. Result of test experiment. Rate of initial temperature increase with time varies systematically with the sample's $\sqrt{k\rho c}$. (1u=0.5s).