MOLECULAR GAS FLOW AND DIELECTRIC PROPERTIES OF LUNAR SOIL

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Several experiments have been initiated to measure physical properties of returned lunar samples under varying thermodynamic conditions. These measurements include dielectric properties, molecular flow of gases, thermal diffusivity and sonic velocities in lunar soils. The topics to be discussed in the present brief paper are the molecular flow of gases and dielectric properties of lunar soil. Dielectric properties of lunar samples have important applications for interpretation of such data as earth based radar observations, the Apollo 17 surface electrical properties experiment, and the Apollo lunar sounder experiment. The dielectric properties of lunar soil sample 72441,12 have been measured as a function of vertical pressure to 29 psi, temperature to $200^\circ C$ and density from 1.56 to 1.87 gm/cm^3 in vacuum over the frequency range $200 - 10^5$ Hz. A molybdenum three electrode arrangement was used in a specially designed vacuum system capable of applying a uniaxial load to the soil sample while under vacuum. The minimum pressure that could be applied to the sample was that due to the weight of the top electrode assembly ($P_o=.52$ psi) and the maximum, without external equipment, was 29 psi. Since the data show the usual observed temperature dependence, values will only be given at room temperature where pressure tests were performed. As shown in Figure 1, for frequencies of 1 Khz and 100 Khz and densities of 1.63 and 1.68 gm/cm^3, the dielectric constant of the soil varies with pressure, the most dramatic effect occuring within the first 6 - 8 psi. Due to the sequence of data collection, data in this graph was recorded from higher to lower pressures. For density of 1.63, the application of pressure was repeated (P_{inc}) as varification of this phenomenon, in this case, the measurements being performed with increasing pressure. Upon reaching P_{max}, the pressure was released and a final data point recorded. The loss tangent was found to be essentially independent of pressure and density in the range measured. These measurements indicate that while the dielectric properties in each sub-layer of the lunar regolith will vary according to the electrical properties in each sub-layer, pressure will always increase with depth and, therefore, increase the value of the dielectric constant. The loss tangent will vary in each sub-layer primarily due to temperature variations, suggesting a possible constraint on models of temperature vs depth. A solid terrestrial basalt sample was ground to a powder and separated to a grain size distribution similar to that of a seived Apollo 15 soil (1). Measurements showed a pressure dependence of the dielectric constant similar to that observed on the lunar soil. Two faces on a remaining slab of the solid basalt were ground flat and, with the soil, provided the basis for measurements over a large density range. The variation of dielectric constant with density for lunar sample 72441,12 and the basalt soil are shown in Figure 2 for frequencies of 1 and 100 Khz. To eliminate pressure effects, all data in this graph are given at $P = P_o$. Using the dielectric data for the solid basalt, the Rayleigh (2) and Lichtenecker (3) mixing formulas have been used to calculate dielectric constant as a function of density and are also shown in Figure 2. Comparison of the calculated and measured values demonstrates

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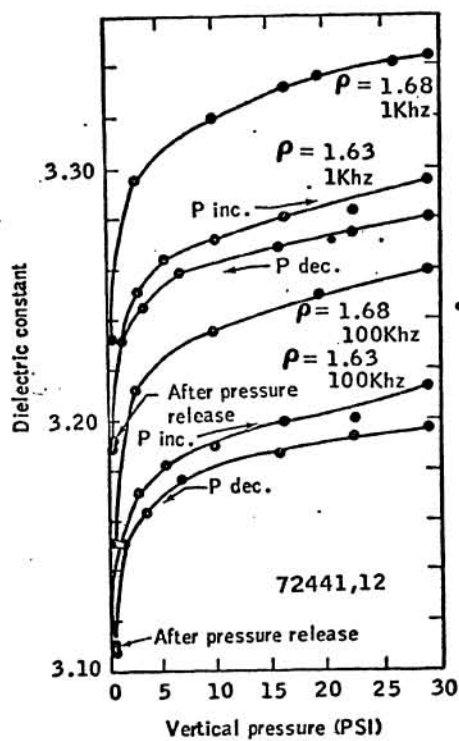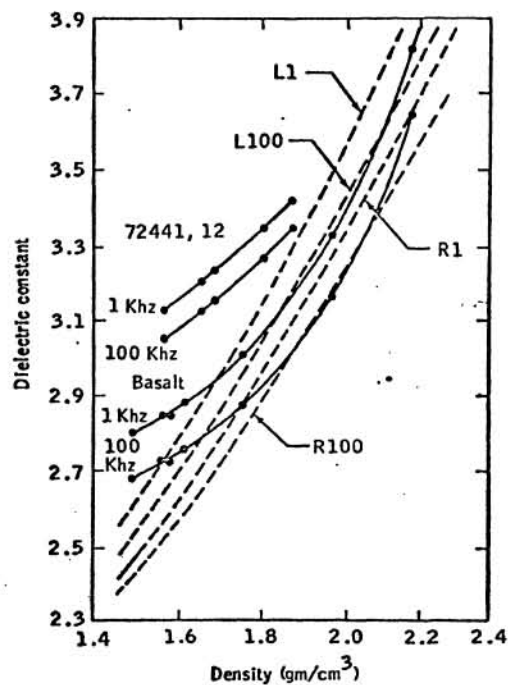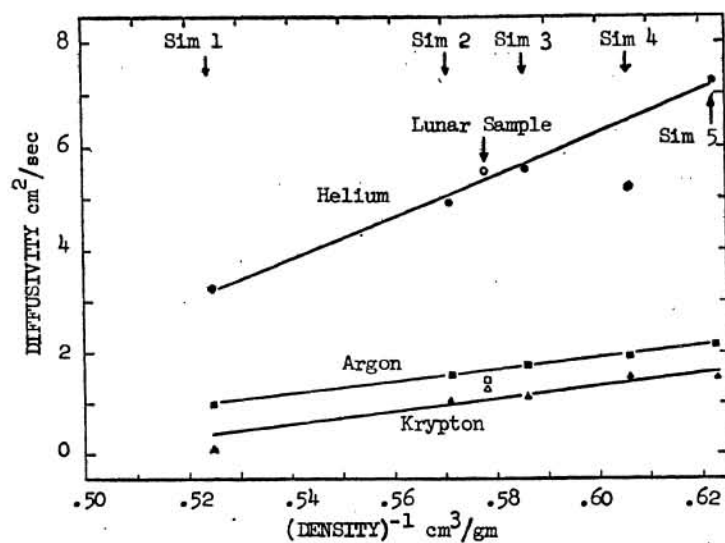
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Figure 1

Figure 2

Figure 3

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that neither mixing formula fit the measured basalt data except over a limited density range. Attempts were made to fit the measured data using the dielectric constants obtained at densities of 1.75 and 1.96 as the high density end point to examine possible usefullness of the mixing formulas over a small density range. Although nearly identical calculated results were obtained using the two mixing formulas, the calculated and measured values were in major disagreement.

The measurement of molecular flow of gases through lunar soil is important to develop an understanding of the nature of gases beneath the lunar surface and their rates of movement through the regolith. These parameters may be useful in understanding the high anomolous argon 40 content of lunar soils and the tenuous lunar atmosphere, both of which are probably related to seepage of gases from deep in the regolith. Measurements are being performed using three gases, He, Ar, and Kr, selected to provide data over a wide range of molecular weights. Preliminary tests were performed on a terrestrial basalt sample having a grain size distribution similar to an Apollo 15 soil (1). This data and the single data point recorded, to date, for lunar soil 71501,35, is illustrated in Figure 3. It is interesting to note that the lunar sample data is very close to the curves obtained using the lunar simulant. The major percentage of grain size in the basalt simulant is 150 microns and below which is comparable to the grain size distribution in the submillimeter soil allocation under study. Furthermore, the major components of 71501,35 in the 90 - 150 and 250 - 500 micron grain size range are basalts and agglutinates (Apollo 17 Lunar Sample Information Catalog). Therefore similiarity of data for the simulant and lunar soil has a qualitative interpretation. Tests to extend the density range for the lunar soil are in progress.

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