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DENSITY MEASUREMENT OF MOON'S SURFACE LAYER BY AUTOMATIC STATION "LUNA-13"

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SUMMARY

This paper gives the description of the first direct experiment on Moon's surface density measurement using the radiometric method of registration of scattered γ-radiation.

It is illustrated by a photograph of radiation densimeter's pickup unit and by a table showing the variation of the counting rate as a function of the relief of lunar surface immediately under specific parts of counters and of the source.

* * *

The first direct measurement of density of Moon's surface layers by the ALS "LUNA-13" was conducted by radiometric method by way of intensity measurement of scattered γ-radiation.

The foundation of the method consists in that a γ-radiation source is applied to the surface of the soil, while at a certain distance from it γ-counters are placed, the latter being shielded by a lead screen from direct irradiation. The γ-quanta, hitting the soil, interact with the latter's matter by way of three processes:

- photoeffect,
- formation of pairs electron-positron,
- Compton-effect.

The first two lead to total vanishing of γ-quantum, that is, they are absorption processes. The Compton-effect is a process of γ-quantum scattering on electrons of the medium. As a result of scattering, there takes place a partial loss of energy, a change in the direction of motion of γ-quanta, part of which, returning to the surface, hit the counters.

(*) IZMERENIYE PLOTNOSTI POVERKHNOSTNOGO SLOYA LUNY AVTOMATICHESKOY STANTSIYEY "LUNA-13"

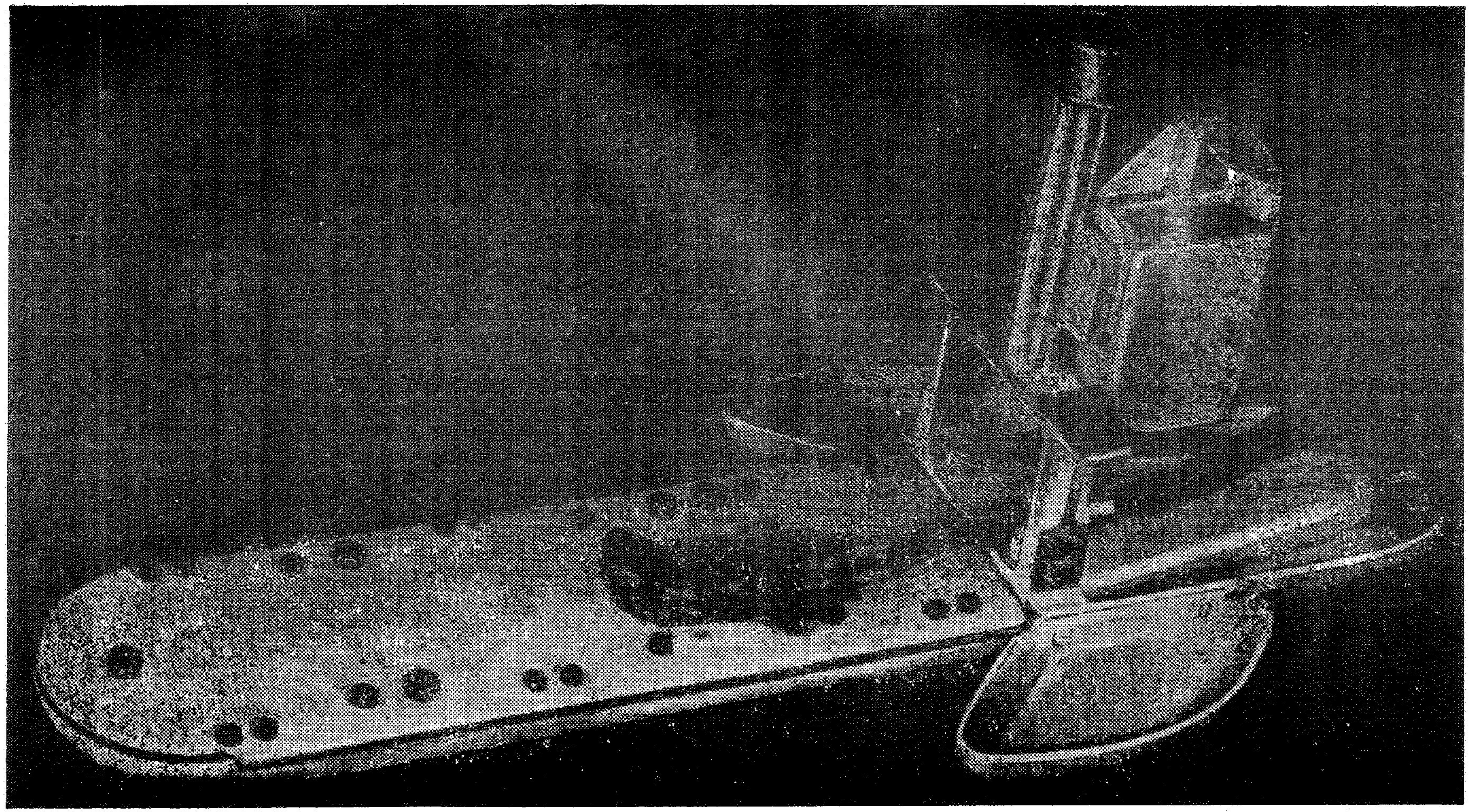


Fig.1. Radiation Densimeter's Pickup Unit

For the γ-method of density measurement the optimum quantum energy range is 0.5 - 3.0 Mev. In this range the fundamental interaction process of γ-radiation interaction with the matter is the Compton-effect, with a characteristic cross-section, proportional to Z(A), where Z is the atomic number and A is the atomic weight of the element. This ratio is nearly identical for all elements contained in mineral soils (with the exception of H), and is equal to 0.5 - 0.4, which assures in a great number of cases the elimination of the influence of matter composition.

When conducting measurements of density by the scattered γ-radiation method, it is customary to take advantage of the functional relationship between the registered intensity of γ-radiation and the density of the medium $N = f(\rho)$. This dependence has a maximum. Its graph may be subdivided into three parts: an ascending branch, the maximum and the descending branch. At the same time the position of the maximum depends on the base of the device L, i. e. on the distance between the center of the counter and the source, the latter's energy and the construction of the radiometric device itself.

Such a character of the dependence is due to the concurrence of two processes of scattering and absorption of γ-radiation. The probability of Compton-effect is proportional to the number of electrons in a unit of volume. This is why the intensity of scattered radiation must rise with the increase of medium's density, which is precisely observed for small values of density. However, as a result of multiple scattering there takes place a decrease of γ-quantum energy and, consequently, the probability of their absorption on account of the photoeffect increases. The absorption begins gradually to prevail, and then, as the density of the medium increases, the intensity of scattered radiation registered by the counter must decrease.

The principal advantage of the described method consists in that the apparatus is disposed on the surface of the soil, thus making any hole boring unnecessary, which has a particular significance for optimum alleviation and miniaturization of the devices. However, to each value of measured intensity of scattered radiation correspond two values of density of the investigated medium, along the ascending and descending branches of the curve, for whose choice additional data must be called for.

The radiation densimeter of LUNA-13 consists of a unit of pickups or sensors and of a monitor unit. The sensor unit (see Plate of Fig.1) was placed on a mechanism assuring its extension after soft landing and opening of ALS's lobes over a distance of 1.5 meters from the probe and a smooth application to the surface of the soil. The registration or monitoring unit was placed in a hermetically-sealed body of the ALS and was connected with the sensor unit by three cables.

A source of γ-radiation, namely a radioactive caesium isotope Cs-137 of 1 mg rad.equiv. was placed in the sensor unit alongside with a separating lead screen and three groups of miniature γ-counters SBM-10M, with 5 counters for each group. The distances between the center of each group from the emission source were different, and the device operated for three different base lengths. The frame of sensor unit had dimensions 258 × 48 × 10 mm; it was provided with two lateral segments so as to facilitate its orientation on the surface of the Moon's siil.

The registration unit consisted of three identical channels (in correspondence with three groups of counters). Triggers on transisors were used in sequence in channels as registering elements. The indication of the number of pulses in discharges of channels was achieved with the aid of summators, also completed on transisotrs. The summator's output signal was the magnitude of voltage that changed in a jump-like fashion in correspondence with trigger reversal, receiving 8 values from 0 to 6 v.

The total number of registered pulses in the channel was determined by way of alternate measurement of voltages at summator output. The step-by-step volatge variation from the outputs of each channel of the electronic registration unit was recorded on telemetry film and processed with the aid of special tables.

For the final deciphering of device's readings tables were compiled and a curve was drawn on the basis of ground calibration in media of different densities, including: heavy concrete, light concrete. keramzite, foam glass and others. The calibration was conducted in density variation range from 0.16 to 2.6 g/cm^3. In the process of calibration the investigation of the energy spectrum of the scattered γ-radiation was also conducted.

Plotted in Fig.2 is the final calibration curve.

Particular attention is given the investigation of the influence of surface roughnesses of the investigated material on device's readings. The presence of gaps between the foot of the unit of sensors and the surface of the soil affects in different ways the registered intensity of γ-radiation in media with different density. Thus, for dense media, located on the descending curve of the dependence $N/N_2 = f(\rho)$, the presence of caverns or of nondense (loose) application induces practically in all cases an increase of the registered integral counting rate. When conducting measurements in media with very low density (to 0.4 g/cm^3) the application density results in a decrease of the counting rate for all bases without radiation densimeter and for other media near the base of the device there are always invesrion points which help to eliminate the influence of contact conditions of measurements.

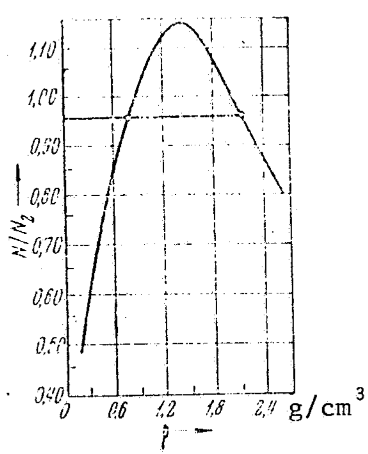
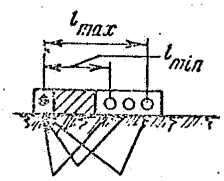
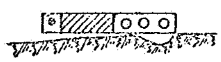


Fig.2. Calibration graph of the radiation densimeter

The results of experiments on the study of influence of caverns with $\sim$ 12 cm^3 volume conducted by means of a radiation densimeter for other media near the base of the device in media with density $\sim$ 0.75 g/cm^3 , are compiled in Table 1 (next page).

TABLE 1

RESULTS OF EXPERIMENTS ON THE DETERMINATION OF SURFACE ROUGHNESS' EFFECT ON THE COUNTING RATE OF GAMMA-QUANTA BY THE RADIATION DENSIMETER

Form of Surface's Relief under the sensor	Counting rate	
	base l_{min}	base l_{max}
 Even surface	1.0	1.0
 Counters above recesses	0.986	1.08
 Counters above recess; 1 cm gap under source	0.936	1.06
 Counters above recess; additional gap under the "fifth"	0.958	1.10
 Source above recess	0.974	1.00
 Recess under the median part of the sensor	0.936	1.18
 Recess inder the source and the detectors	0.963	1.09
 Sensor on "heaps"	0.804	1.21

On the basis of analysis of these data it may be stated that caverns with diameter of $\sim 3 - 4$ cm and depth of 2.0 - 2.5 cm have little or insignificant effect on the variation of counting rate for a given density. The errors constitute 5 to 10 percent depending upon the disposition of the cavern under the plane of the sensor. At the same time for the small base there takes place underrating of the registered intensity, while for the maximum base it is overrated. When the sensor is located on heaps of 2.0 - 2.5 cm height, a significant overrating of the counting rate takes place, of the order of 15 to 20 percent for the base maximum. For the minimum base of the device a counting rate decrease of the same order takes place under identical measurement conditions.

Inasmuch as the device disposed of three groups of counters with different bases, the influence of roughnesses or unevennesses on the averaged result of measurements was substantially weakened. The deciphering of the results of measurements was conducted according to the calibrated graph reduced to a mean base. as is shown in Fig.2. The graph has been constructed taking into account the background of external irradiation on the Moon's surface.

The intensity of scattered radiation registered during the first communication session of 24 December 1966 constituted 0.96 units of N/N_2 (each unit being equal to the average sum of pulses registered by the device in 2 min. while operating on a material of 2.0 g/cm^3 density). To this correspond in the graph of Fig.2 two values of density: $\rho_1 = 0.8$ and $\rho_2 > 2.1$ g/cm^3. The first value is characteristic of light foamy and porous materials of slag, pumice, foam glass and granular material types, especially consisting of light granules. The second refers to dense materials of heavy concrete or rocky type. Inasmuch as the presence of stony formations in the uppermost layer of lunar soils is in contradiction with most of astronomical, photographic and radiophysical investigations, the density $\rho_1 = 0.8$ g/cm^3 was acknowledged as being more trustworthy. This quantity refers to a layer of about 15 cm thickness, over which the zone of action of radiation densimeter spreads.

****** T H E E N D ******

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