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THE STUDY OF INTERPLANETARY IONIZED GAS, HIGH-ENERGY ELECTRONS AND CORPUSCULAR RADIATION OF THE SUN, EMPLOYING THREE-ELECTRODE CHARGED PARTICLE TRAPS ON THE SECOND SOVIET SPACE ROCKET*

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Experiments with three-electrode charged particle traps were carried out on the first, second and third Soviet space rockets. The most statistically valuable material from these experiments (approximately 12,000 separate collector-current measurements) were obtained during the flight of the second space rocket. The following paper therefore mainly sets out data from this flight.

The volume of information obtained on the operation of three-electrode traps on the first space rocket was considerably smaller; the data from the automatic interplanetary station (third space rocket) have only been partially treated up to the present time. Nevertheless, considering the importance of the observed reproducibility of the results, individual extracts will be introduced below from data obtained during the flight of the first and third space rockets.

On the Soviet space rocket launched to the moon on 12th ~~November~~ Sept. 1959 an experiment was carried out for studying interplanetary ionized gas, electrons with energies W exceeding approximately 200 eV and corpuscular radiation of the sun. During the time of the rocket flight, by means of the radiotelemetering system, records were made of the electrical currents set up by the charged particles entering traps installed on a container with scientific instruments separated from the rocket. Four three-electrode traps were installed on the surface of the container arranged around the peaks of a tetrahedron described in a sphere. Each trap consisted of a hemispherical outer nickel grid (with radius 30 mm), within which there was a flat nickel collector. Between the collector and the outer grid there was a flat tungsten inner grid (Fig. 1). The potentials of the electrodes of the traps relative to the body of the container were: collectors $\varphi_k = -(60\text{–}90)$ V, inner grids $\varphi_{g1} = -200$ V; the outer grids of the four traps had different potentials: $\varphi_{g2} = -10, -5, 0$ and $+15$ V.

The main purpose of the inner grids was the suppression of photoeffect from the collectors under the effect of ultraviolet radiation of the sun, together with suppression of secondary electron emission due to bombardment of the collectors by electrons and protons.

Different potentials were applied to the outer grids of the traps in order to provide the possibility of evaluating the energy of positive particles entering the traps and in particular to differentiate the currents which might be formed by protons of the interplanetary stationary plasma (with energies in the order of 1 eV) from currents formed by protons of corpuscular streams, having energies three orders higher. Electrons of stationary plasma (with energies up to a few electron volts) and solar corpuscular streams (with energies up to 25 eV) do not participate in the formation of the collector currents of the traps since they

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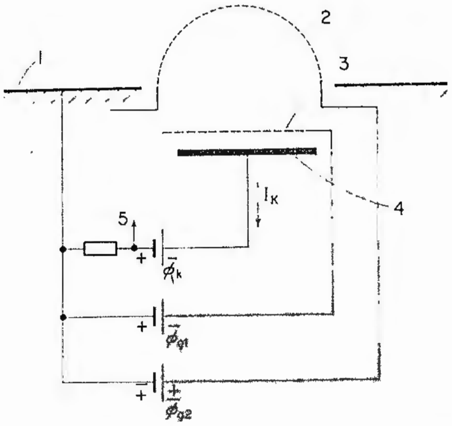

FIG. 1. DIAGRAM OF THE THREE-ELECTRODE TRAP.
1—body of the container; 2—outer grid; 3—inner grid; 4—collector; 5—to collector current amplifier.

cannot overcome the retarding field set up by the potential difference between the inner and outer grids (equal approximately to −200 V). However, electrons entering the magnetic trap of the earth (in the so-called outer radiation belt), possessing sufficient energy to overcome the retarding field between the grids of the trap, may form a negative collector current.

It should be borne in mind that the negative collector current is formed partly also by photoelectrons emitted by the inner grid under the illumination of the sun and striking the collector under the effect of the electric field between this grid and the collector. It is significant further that in the trap not illuminated by the sun (the traps were located on the container in such a way that one of them was in shadow at any given moment) a negative current can be formed only by high-energy electrons retained by the geomagnetic field.

In selecting the instrument characteristics the following models of interplanetary gaseous medium were taken as the most probable (in accordance with the available literature data$^{(1-4)}$).

A. There is a stationary gaseous medium consisting mainly of ionized hydrogen with a concentration $n_i = 5 \times 10^2$–10^3 cm^{-3}, with an electron temperature in the order of 10^4 °K, near to the ion temperature.

B. There are only sporadic corpuscular streams consisting of protons and electrons with velocities (1–3) × 10^8 cm/s and with concentrations $n_i = 1$–10 cm^{-3} rising sometimes to $n_i \approx 10^3$ cm^{-3}.

There was also in mind the possibility of a case C—the simultaneous occurrence of A and B. It was anticipated that in the case A there would be observed a diminution in the collector currents I_k with increasing φ_{g2} and an absence of positive currents I_k with $\varphi_{g2} = +15$ V. In case B the positive values I_k must be identical and independent of the value φ_{g2}. In case C positive values I_k must be observed in all the traps, but falling off with increasing φ_{g2}.

The collector current amplifiers and the telemetering system provided the possibility of recording positive collector currents from 10^{-10} to 50×10^{-10} A and negative collector currents from 10^{-10} to 15×10^{-10} A. Instantaneous values of each collector current were recorded twice per minute.

Whilst travelling along the trajectory, the container with the scientific instrumentation carried out simultaneously complex high-speed rotational motions. Due to this the orientation of each trap relative to the velocity vector and direction to the sun varied continuously giving rise to corresponding fluctuations in the collector current (Fig. 2.). The

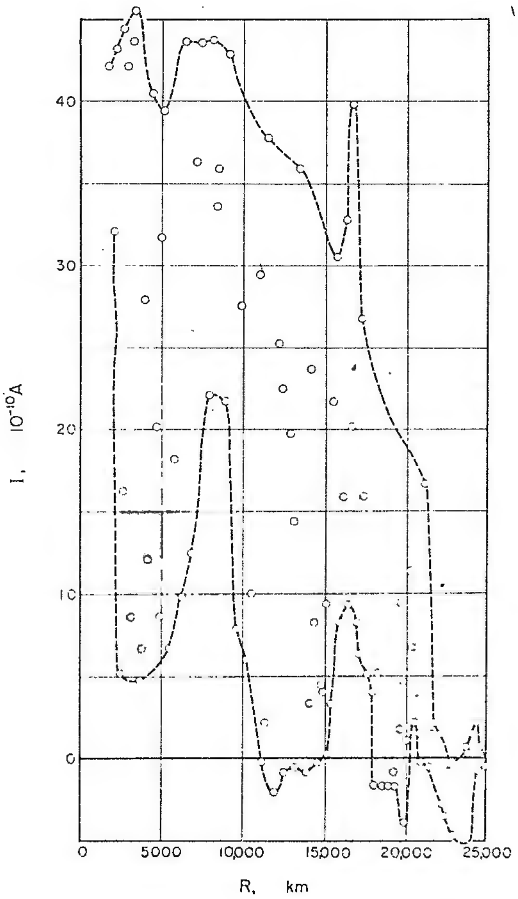

FIG. 2. COLLECTOR CURRENT VALUES RECORDED IN THE TRAP WITH $\varphi_{g2} = -10$ V ON THE SECTION $R < 25{,}000$ km.

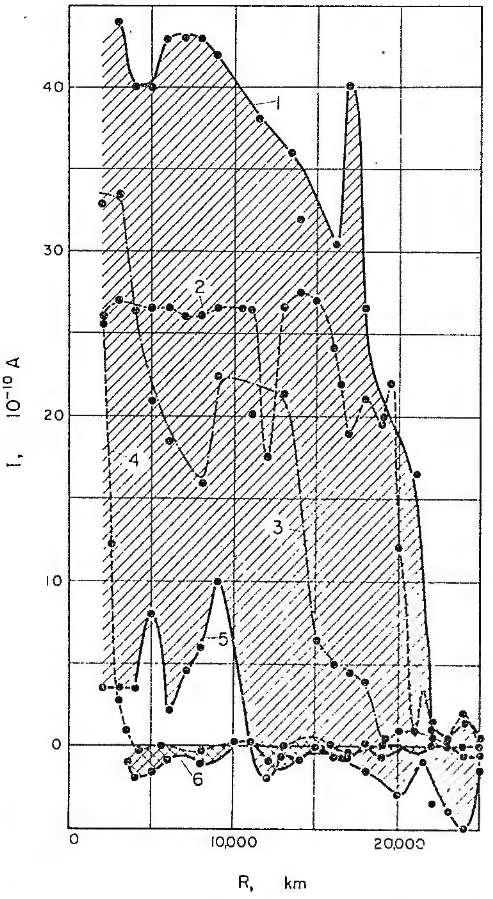

FIG. 3. COLLECTOR CURRENT LIMITS ON THE SECTION $R < 25{,}000$ km; Upper limits: 1—with $\varphi_{g2} = -10$ V, 2—with $\varphi_{g2} = -5$ V, 3—with $\varphi_{g2} = 0$ V and 4—with $\varphi_{g2} = +15$ V; lower limits; 5—common for traps with $\varphi_{g2} = -10$, -5 and 0 V, 6—with $\varphi_{g2} = +15$ V.

highest (and also the smallest) values corresponded to certain container orientations near to each other. Hence variations in the values of I_k along the trajectory, depending principally on the ambient medium, can be described by means of curves enveloping the largest and smallest values of I_k; at the same time the influence of container rotation on the results of the experiment can to some degree be excluded.

Figure 3 shows in a similar way the experimental results on a section of the trajectory corresponding to distances from the earth's surface less than 25,000 km and Fig. 4 shows the results relating to distances from 25,000 km up to the container reaching the moon.

The lack of similarity in the trend of the curves of Fig. 3 is due apparently to features of variations in the orientation of the various traps relative to the velocity vector of the spherical container associated with their different location on the surface of the container rotating in a complex manner.

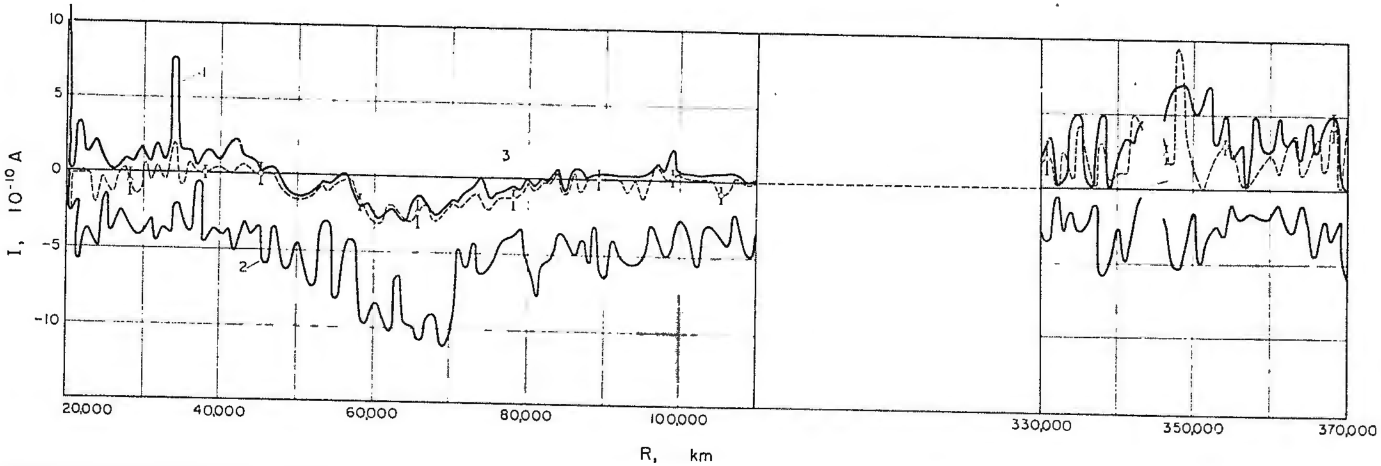

FIG. 4. CURVES 1 AND 2—RESPECTIVELY COMMON UPPER AND LOWER COLLECTOR CURRENT LIMITS IN TRAPS WITH $\varphi_{g2} = -10, -5$ AND 0 V. CURVE 3—UPPER CURRENT LIMIT IN THE TRAP WITH $\varphi_{g2} = +15$ V.

The curves relate to two sections of the trajectory; the end of the first section (from 110,000 to 190,000 km) is omitted since as regards the nature of currents this corresponds to the section from 80,000 to 110,000 km; the beginning of the second section (from 245,000 to 330,000 km) is omitted since this corresponds as regards nature of the currents to the section from 330,000 to 370,000 km.

On 13 September 1959 at 2.15 hr Moscow time, when the container was at a distance $R \approx 190{,}000$ km from the earth, radio-communication between the container and the territory of the U.S.S.R. was interrupted since at that time it was passing over the Western hemisphere of the earth. After renewing contact the nature of the recorded collector currents varied and were as in the last section of Fig. 4 up to the end of the experiment.

A study of the experimental data produced indicates:

1. At distances R from the earth's surface up to four earth radii a plasma was observed with temperature not greater than tens of thousands of degrees. This follows from the substantial influence of relatively small differences (equal to 5 V) between the potentials of the outer grids of the traps as clearly visible from Fig. 3, on the value of the collector currents and from the absence (at distances $R > 3{,}000$ km) of current in the trap with positive potential of the outer grid. The existence of plasma at these distances from the earth is confirmed by results obtained on the first space rocket in January 1959 and on the third space rocket in October 1959 (in the latter case up to 7000 km, since at this distance the first radiocommunication session with the automatic interplanetary station ceased). Questions connected with evaluations of plasma concentration observed by us together with the possible concentration of interplanetary plasma (for large R), are outside the scope of the present report and are considered separately in (5).
2. On the section $55{,}000 < R < 75{,}000$ km the electron flux was recorded $N_e \sim 10^8$ cm^{-2}/s with energies exceeding approximately 200 eV. This is due to the fact that whilst the container was passing through this section (more than 1.5 hr) only negative currents were recorded in all the traps which, in accordance with what has been stated earlier, is possible only under the action of high-energy electrons The existence of this type of electron flux in the zone of this section of the rocket trajectory is confirmed by results of the experiment on the first space rocket in January 1959.
3. Starting from 9.30 hr Moscow time on 13 September 1959 up to the moment of the container of the second space rocket reaching the moon the container was recorded as passing through a positive ion flux (in all probability protons) with energies exceeding 15 eV; $N \sim 2 \times 10^8$ cm^{-2}/s. This follows from the fact that during this time approximately identical positive collector currents were recorded in all four traps (see the last section of Fig. 4.)

The existence at a different time of a proton flux with energies exceeding 25 eV was observed employing similar instrumentation at different distances from the earth (in particular with $R \sim 125{,}000$ km) during a number of radiotelemetering data transmission sessions during the flight of the automatic interplanetary station in October 1959.

The proton fluxes recorded refer evidently to solar corpuscular radiation observed for the first time in this manner in interplanetary space outside the earth's magnetic field.

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