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PRELIMINARY RESULTS OF MEASUREMENTS BY AUTOMATED PROBES VEGA 1 AND 2 OF PARTICLE CONCENTRATION IN CLOUDS OF VENUS AT HEIGHTS 47-63 KM

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Translation of "Predvaritel'nyye rezul'taty izmereniya na AMS "Vega-1" i "Vega-2" kontsentratsiy chastits v oblakakh venery na vysotakh 47-63 km", Pis'ma v AZh, vol. 12, No. 2, 1986, pp. 123-130.

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16. Abstract
Results of the preliminary processing of the Vega 1 and Vega 2 descenders' data on the cloud layer structure of the Venusian atmosphere are discussed. A photoelectric counter for aerosol particles is described together with its optical and pneumatic circuits and operation algorithm. Vertical profiles of concentrations of particles with a diameter of 0.4 μm agree qualitatively with the Pioneer-Venus and Venera 9 and Venera 10 data. Concentrations of these particles are: in the B layer, up to $1.9 \cdot 10^2$ cm^{-3}; in the C layer, up to 10 cm^{-3}, in the D layer, up to $1.3 \cdot 10^2$ cm^{-3}. Layers have sharp boundaries with a significant vertical heterogeneity of the aerosol concentration field inside them.

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PRELIMINARY RESULTS OF MEASUREMENTS BY AMS VEGA 1 AND VEGA 2 OF PARTICLE CONCENTRATION IN CLOUDS OF VENUS AT HEIGHTS 47-63 KM

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In order to understand processes of the formation and evolution /123* of the Venusian atmosphere, particular features of circulation and climate, investigations of its aerosol component are very important. Together with the gas component, it basically determines the optical and thermoradiation properties of the Venusian atmosphere and processes of the absorption and scattering of solar radiation. In this connection, within the framework of the "Venera" program, an experiment was planned on the landers to study the vertical concentration profile and the spectrum of particle dimensions in the cloud layer of Venus.

Method of the Investigation

As the method of investigation, a photoelectric method of analyzing aerosols was selected; this method provides for the conversion of a parameter being measured (particle dimension) into an electrical signal which is convenient for further processing and transmission to earth. In order to ensure a constant and known discharge of atmospheric air during landing, the forced pumping of gas to be analyzed by a rotor pump was used. The broad range of working pressures and the variable landing velocity prevented the use of the pneumatic /124
scheme which is traditional for photoelectric counters, in which a flow of gas to be analyzed, which with a known and constant

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* Numbers in the margin indicate pagination in the foreign text.

velocity intersects the illuminated sensitive volume in the "housing" of the pure filtered air, forms in the intake capillary; this ensures the stability and limited space of the flow of aerosol from the capillary (Belyayev et al., 1981).

An optical scheme proposed by Deryagin et al. (1962) was used in this work. An important feature of this scheme (for conditions of a lander) is the possibility of separating for analysis a stream of the necessary diameter from the total gas flow by an optical method, rather than forming it with the help of a capillary.

In conducting the experiment in the Venusian atmosphere it was essential to consider that the counting characteristic (the dependence of the measured concentration on the true value) of the counters is ambiguous (Oeseburg et al., 1979), i.e. that two values for the true concentration of the particles (one in the working section of the counting characteristic, before the discontinuity and the second after the discontinuity, when the device operates in the overflow regime) correspond in principle to the concentration value measured by the device. In this connection, the parameters of the optical scheme were selected in such a way as to extend the working section of the counting characteristic into the range of high concentrations (up to 10^3 cm^{-3}). On the other hand, in individual sections of the landing trajectory, the parameters of the air dispersed system were determined; on the basis of these it is possible to do an independent calculation of the concentrations of particles using a method described in the work of Zhulanov et al. (1984).

The Construction and Basic Nodes of the Counter

The photoelectric aerosol detector LSA which was installed in the lander of AMS "Vega-1" and "Vega-2" consists of two basic blocks: a block of an optical detector with a pumping system and an analysis block. The optical detector ensures recording of individual aerosol particles as they intersect the sensitive volume and the

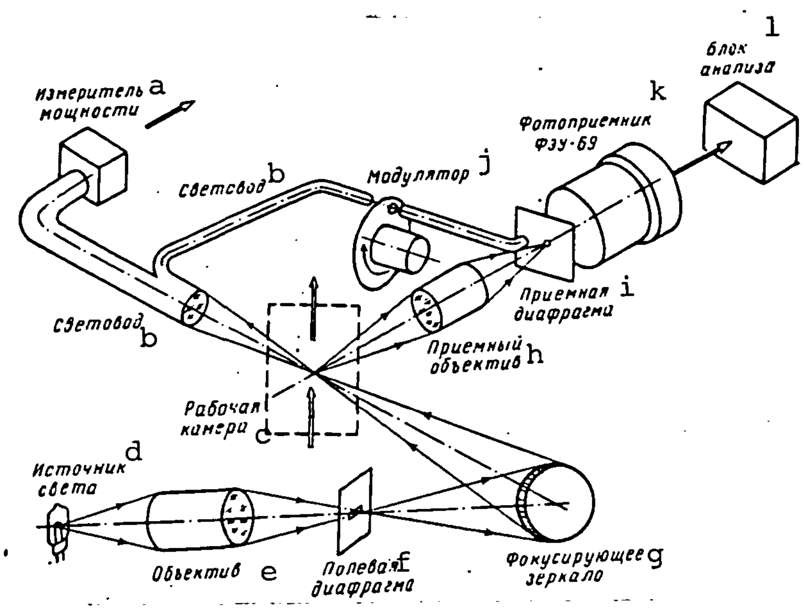

Fig. 1. The optical line diagram of the LSA detector

Key: a-Power meter
b-Light guide
c-Working chamber
d-Light source
e-Objective
f-Field diagram
g-Focussing mirror
h-Receiving objective
i-Receiving diaphragm
j-Modulator
k-FEU-69 photoreceiver
l-Analysis block

transformation of impulses of light scattered by the particle (light carries information about its size) into an electrical signal (voltage impulse). The analysis block ensures processing of incoming impulses by the assigned program and the transmission of results to earth.

a) The optical diagram of the aerosol detector consists of an optical diagram of an illuminator and an optical diagram of a receiver. The optical line diagram of the detector is shown in fig. 1. As the light source an incandescent halogen lamp was used. The image of the filament was projected by the objective onto a field diaphragm with a rectangular slit of 1.2x0.2 mm. The image of the illuminated slit is projected by the focussing mirror into the working chamber. The illuminating light beam coming from the chamber falls on the light guide which, bifurcating, divides it into two parts. One part falls on the radiation power meter, from which, during the entire working time of the detector, information is received. The other part of the radiation falls on the mechanical modulator which in the assigned period of time forms a parcel of (10-15) light impulses which go to the photoreceiver. The amplitude /125 of these impulses is also transmitted to earth by telemetry.

Information from the power meter makes it possible to determine deviations in the intensity of illumination of the sensitive volume from the nominal value and from the amplitude of the calibrated impulses to determine changes in the sensitivity of the recording photoreceiver. On the whole, both control parameters make it possible to fix the deviation of the sensitivity of the detector from that established during ground based calibrations of it by monodispersed latex aerosols.

The optical diagram of the receiver consists of a receiving objective which collects light scattered by the particles in a solid 55° angle and focusses this light on the receiving diaphragm behind which is the photoreceiver. The pattern of the intersection of the light beam and the aerosol flow in the working chamber is projected by the objective onto the receiving diaphragm. In this case the photoreceiver "sees" only part of the intersection pattern - the sensitive volume - through the diaphragm. The diameter of the diaphragm and the thickness of the illuminating light beam in the working chamber determine the size of the sensitive volume. Thus, in the optical diagram used, a small zone - the sensitive volume - is separated in the total flow of gas to be analyzed by an optical method.

According to Knollenberg and Hunten's (1979) data, the number of particles of diameter ≥ 0.6 μm in the cloud layer of the Venusian atmosphere reaches $\sim 5 \cdot 10^2$ cm^{-3}. Taking account of these data, the size of the sensitive volume ($5 \cdot 10^{-5}$ cm^3) was selected such that it was possible to record concentrations up to 10^3 cm^{-3} with an error of correspondence of not more than 5%. According to data of Rossow et al. (1980), the cloud layer of Venus is heterogeneous and it is not known whether Knollenberg and Hunten's (1979) data refer to the region of minimum or maximum concentrations and for this reason the maximum concentration measurable by the LSA is taken with an allowance. /126

Calibration of the aerosol detector, i.e. establishment of the dependence of the amplitude of the impulse on particle size, was done by a set of monodispersed latex aerosols. The sensitivity of the detector itself was 0.3 μm and the broadening of the spectrum of dimensions at the half altitude was ~15%. At the established nominal sensitivity, the current from the power meter and the amplitude of the calibrated impulses from the photoreceiver were fixed.

b) The structural diagram of the analysis block is shown in fig. 2. When the particles intersects the sensitive volume, the impulse of the light scattered by it is recorded by the FEU-69 photoreceiver, from the output of which comes a current signal which is proportional to the intensity of the scattered light. The "current-voltage" transformer transformed the current impulses into voltage impulses, the amplitude of which was proportional to the dimensions of the particles. These impulses were recorded on four measurement channels.

1. The first channel records impulses, the amplitude of which exceeds the amplitude of impulses from particles of diameter ≥ 0.35 μm, from the amplifier for the photocell.

2. The second channel, the input comparator of which is adjusted to a higher threshold voltage than in the first channel, makes it

possible to obtain a vertical profile of the concentrations of particles of diameter ≥ 0.4 μm with the same spatial resolution as in the case in which during the operation of the device on the lander the adjustments turn out to be above the response threshold of /127 the comparator of the first channel and it will be blocked.

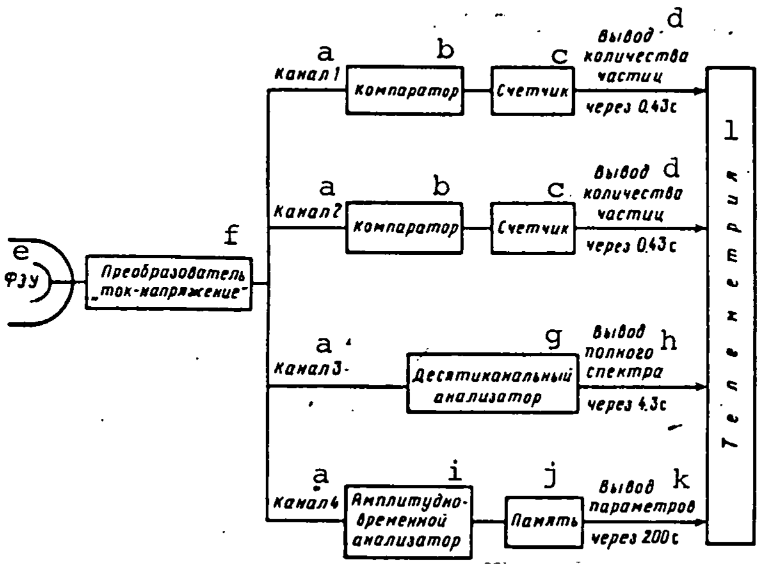

Fig. 2. Structural diagram of the analysis block of the LSA

Key: a-Channel
b-Comparator
c-Counter
d-Output of a number of particles in 0.43 s
e-Amplifier for photocell
f-"Current-voltage" transformer
g-Ten-channel analyzer
h-Output of the entire spectrum in 200 s
i-Amplitude-time analyzer
j-Memory
k-Output of parameters in 200 s
l-Telemetry

3. The third channel performs an amplitude analysis of the impulses coming in from the detector and it is a 10-channel differential analyzer. It makes it possible to obtain a spectrum of the dimensions of the particles in the sample to be analyzed. The number of particles in each of the 10 channels is by turns, with an interval of 4.3 s, put out in digital form to the telemetry. The sensitivity threshold of this channel was established to be still higher, it records particles of diameter ≥ 0.5 μm. This was also done from considerations of duplication, in the case of blockage of both the first and second channels during strong adjustments on board the lander.

4. The fourth channel measures the amplitudes of the impulses

coming from the particles (with the help of a 256-channel amplitude analyzer), their duration and the time until the next impulse. The temporal diagram of the operation of this channel ensures that we will obtain five spectra of the dimensions of particles which are evenly arranged along the working section of the landing trajectory (with an interval of ~100 s). In this channel, calibrated impulses from the mechanical modulator, which responded at the beginning of the recording of each spectrum, were also recorded. The separation of the calibrated impulses from the mass of impulses from the particles is done on the basis of their short duration (in comparison with the duration of impulses from the particles) and the regularity with which they come. /128

Experimental Results

During the experiment conducted on 11 and 15 June 1985, both aerosol counters on the AMS "Vega-1" and "Vega-2" landers were switched on at altitude ~63 km and finished their work in the working section of the landing trajectory (to altitude ~47 km) in accordance with the assigned program. An analysis of the control parameters revealed a drop in the sensitivity of the counters (~15%) in comparison with that established during the ground calibration because the supply in the light source was lower than the nominal value. Preliminary calculations showed that evidently, because of this, the first channel recorded particles of diameter ≥ 0.4 μm.

The averaged vertical profiles of the concentrations of particles of diameter ≥ 0.4 μm which were calculated from the data obtained on the concentrations of particles (with interval 0.43 s) for both experiments with temporal resolution 4.3 s are presented in fig. 3. As is clear from the figure, in these experiments, which were conducted on the night side of the planet at an interval of 4 days, identical concentration profiles were obtained (these coincide in their basic features with the profiles obtained by ISAV-A devices). This confirms the existence of a stable structure of the

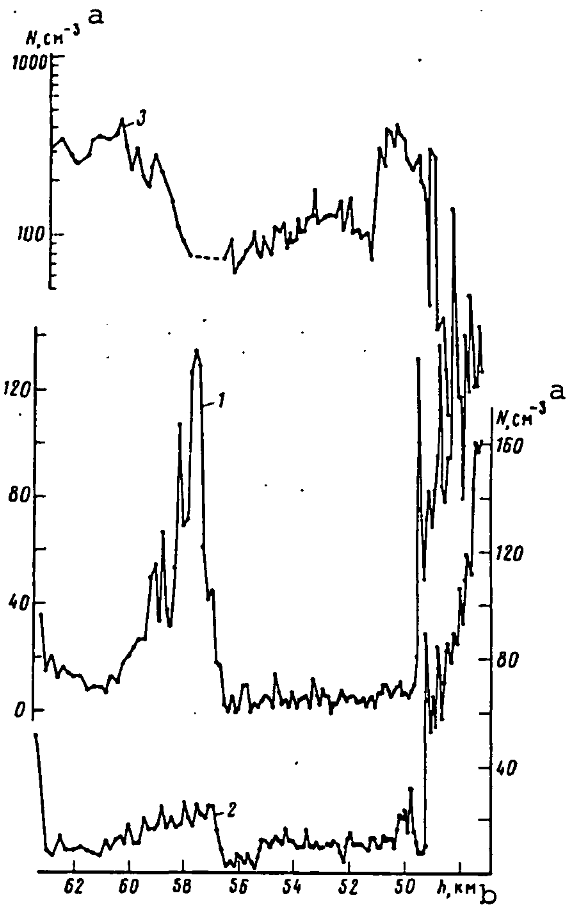

Fig. 3. Vertical profiles of the concentrations of particles of diameter >0.4 μm in the cloud layer $\bar{h}$=47-63 km according to experimental data: 1-"Vega-1", 2-"Vega-2", 3-"Pioneer-Venera" (Knollenberg and Hunten, 1980).

Key: a-N, cm^{-3}
b-h, km

cloud layer of the Venusian atmosphere. In the second experiment the concentration of particles in the upper cloud layer turned out to be perceptibly lower than in the first; this indicates its horizontal heterogeneity which was noted in works of Rossow et al. (1980) and Moroz et al. (1982). We must note also the significant vertical variability of the concentrations of aerosols inside the cloud layers.

According to the results of previous experiments - nephelometric experiments (Marov et al., 1978; Ragent and Blamont, 1980) and the spectrometry of dimensions (Knollenberg and Hunten, 1980), several stable cloud layers are isolated in the cloud layer in the range of altitudes from 47-63 km:

upper cloud layer, layer D	above 57 km
intermediate layer C	50-57 km
lower cloud layer, layer B	47-50 km

A comparison of the profiles of particle concentrations in the cloud layer of the Venusian atmosphere obtained in the "Vega" experiment with the profile obtained in the basic "Pioneer-Venera" probe shows their good qualitative agreement. The following quantitative differences exist:

a) The levels of particle concentrations in the upper (up to $1.4 \cdot 10^2$ cm^{-3}) and lower (up to $1.9 \cdot 10^2$ cm^{-3}) cloud layers are lower than those obtained in the "Pioneer-Venera" experiment. The concentrations of particles (~10 cm^{-3}) in intermediate layer C also turned out to be substantially (by approximately one order of magnitude) lower. The discrepancies found may result from the spatial and temporal heterogeneities of the concentration field of aerosols in the Venusian atmosphere.

b) A downward shift was observed in the boundaries of the separate cloud layers. The agreement of the boundaries of the cloud layers in the two experiments at 4 day intervals on the night side and their upward shift on the day side may indicate that these boundaries are related to definite temperature levels (isotherms). On the day side the isotherms rise and the rise in the boundaries of the cloud layers in "Pioneer-Venera" is related to this; on the night side the isotherms drop and this is accompanied by a drop in the boundaries of the cloud layers. The relation between the boundaries of the cloud layers and the isotherms and the clarity of these boundaries allow us to propose that they result from phase conversions of the components of the Venusian atmosphere which are accompanied by the formation of a dispersed phase. This is confirmed by the fact that the sharpness of the boundaries of the cloud layers is maintained under conditions of well-developed vertical turbulence.

Preliminary Conclusions

1. The structure of the cloud layer of the Venusian atmosphere in the range of altitudes of 47-63 km which was obtained by a photoelectric method in the "Vega" experiment basically agrees with the results of the "Venera-9", "Venera-10", "Pioneer-Venera" and "Vega" (ISAV-A) device experiments. The vertical particle concentration profiles which were obtained indicate pronounced boundaries between layers B, C and D.

2. The levels of concentrations of particles of diameter ≥ 0.4 μm which were measured on the night side in all layers (especially in layer C) are substantially lower than in the similar experiment done on "Pioneer-Venera" on the day side of the planet.

3. Cloud layers are evidently formed during phase conversions of components of the Venusian atmosphere and their position is determined by the altitude of the isotherms which correspond to these phase conversions.

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