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VERTICAL THERMAL STRUCTURE OF THE VENUS ATMOSPHERE FROM TEMPERATURE AND PRESSURE MEASUREMENTS

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Translation of "Vertikal'naya termicheskaya struktura atmosfery Venery po dannym izmereniy temperatury i davleniya posadochnym apparatom 'Vega-2'. Predvaritel'nyye rezultaty," Pism'ma v AZh, Vol. 12, No. 2, 1986, pp. 100-105.

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16. Abstract

Accurate temperature and pressure measurements were made on the Vega-2 lander during its entire descent. The temperature and pressure at the surface were 733 °K and 89.3 bar, respectively. A strong temperature inversion was found in the upper troposphere. Several layers with differing static stability were visible in the atmospheric structure.

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1. Characteristics of sensors and measurement cyclogram. /100*
The principal thermodynamic parameters of the ambient medium were measured on board the Vega-2 lander using two temperature sensors T1 and T2 and three pressure sensors P1, P2, and P3. These sensors, together with the electronics bay, comprised the "Meteo" instrument. Platinum resistance thermometers served as the temperature sensors. The T1 sensor was made in the form of an open platinum wire wound bifilarly on a ceramic frame so that there were no mechanical stresses in it. The T2 sensor was also a platinum wire, placed--for protection from the corrosive ambient medium--inside a slender ceramic housing. The different construction of the temperature sensors was selected based on the following requirements: the need for a small time constant of the sensors, resistance to considerable mechanical overloading and the corrosive action of the ambient medium, and the need for different time constants of the sensors for measurements with high sensitivity to small /101 temperature fluctuations over a wide temperature range. The first requirement was satisfied best with a sensor made of an open thin wire. As for this sensor, there were misgivings since a thin open wire had been used in the temperature sensors on four "Pioner-Venera" probes (Seiff et al, 1980) and all these sensors gave invalid measurements in the cloud cover (presumedly owing to their electrical short-circuiting by cloud layer particles). Nonetheless, an open platinum wire with additional protection against short-circuiting between the coil turns and at the mounting areas was ultimately chosen as the

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

low-inertia sensor. The time constants of the sensors under normal conditions and with dry air sweeping past them at a velocity of approximately 7 m/s were as follows: τ_1 (sensors T1) $\approx$ 0.1 s; τ_2 (sensor T2) $\approx$ 3 s. The measurement range was from 200 to 800 °K; the accuracy of measurements with allowance for errors in the electronics was ± 0.5 °K.

The sensors were mounted in the lower part of the lander, in the gap between the toroidal shock absorber assembly and the hermetic housing. The aerodynamic tests of the lander mockup showed that in all the allowable descent regimes, the sensors were swept with a flow that was unperturbed as to temperature.

The pressure sensors P1 and P2 were designed for measurements during the descent sectors that were of highest interest from the standpoint of atmospheric structure: as the lander passed through the cloud layers, the subcloud zone, and the middle atmosphere. Accordingly, sensors ensuring an accuracy of measurements higher than on preceding landers and probes were used. In these sensors a quartz resonator connected to the electrical circuit of a self-excited oscillator was the sensitive element. The frequency of the quartz resonator varied as a function of the mechanical stresses transferred to it from the ambient pressure. Sensor P3 served in measurements during the lower descent sector. A specific requirement was imposed on it--exclusion of the possibility of dehermetization and the incursion of the high ambient pressure within the hermetic housing of the lander through the inlet connection pipe and the sensor housing. A membrane type pressure sensor, specially developed for this experiment, with a capacitive method of measuring membrane displacements was used. The range of measurements using the pressure sensors P1, P2, and P3 was, respectively: 0-2, 0-20, and 2-110 bar, and the absolute accuracy of the measurements was $\sim$1, $\sim$10, and $\sim$500 mbar, respectively, for ΔP1, ΔP2, and ΔP3.

Sensors P1 and P2 were placed in the outer separate thermally insulated hermetic container protecting them against high temperatures and pressures to the level ∿30 bar. The measured pressure was applied against the sensors via short tubes. The hermetic container of the P1 and P2 sensors was installed on the toroidal shock absorber assembly of the lander; the inlet openings of the tubes were in the lower part of the torus. During the descent, the temperature inside the hermetic container was monitored; at the instant the container underwent dehermetization (∿30 bar) the temperature did not exceed 320 °K at an outside temperature of ∿600 °K.

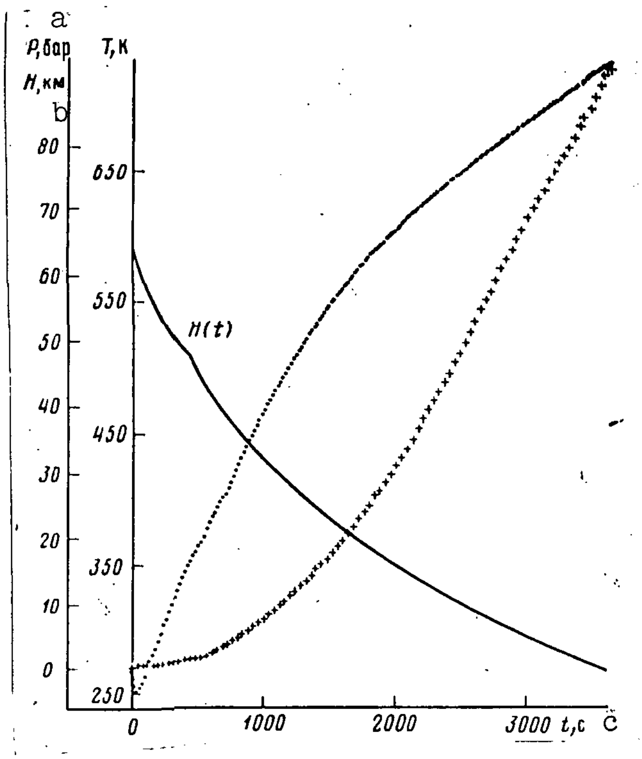

Fig. 1. Results of measurements of temperature (points) and pressure (crosses). Time was measured from the instant T3. Solid line--lander altitude as a function of time
Key: a. bar b. km c. seconds

The P3 sensor was installed inside the main hermetic housing of the lander and operated during both the descent and on the surface. /102

In the results of pressure and temperature measurements present below, no allowance was made for the incident flow. From the results of aerodynamic measurements, these corrections are insignificant. In the following they will be introduced in the final data of pressure and temperature measurements.

The temperature measurements began from the instant T3 = 35 s before the lower hemisphere of the lander was jettisoned and continued during the entire descent and on the surface. The pressure was measured from the instant T3 + 3 s. The temperature sensors were interrogated every 0.2 s; their signals together with

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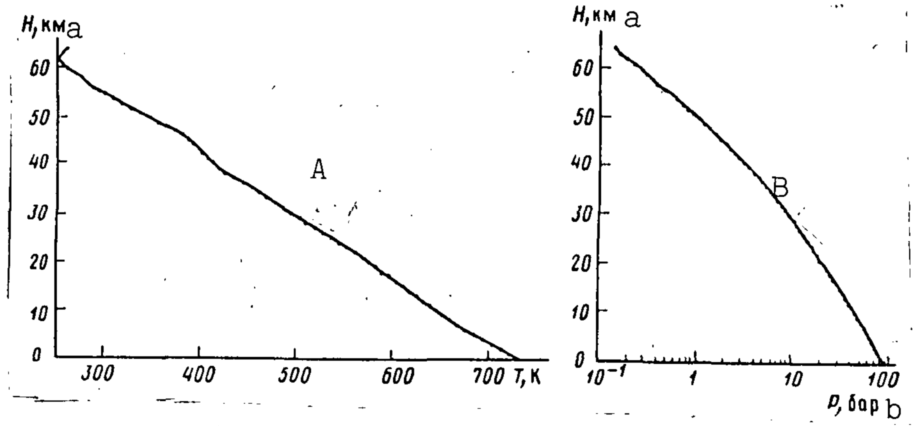

Fig. 2. Temperature and pressure as functions of altitude
Key: a. km b. bar

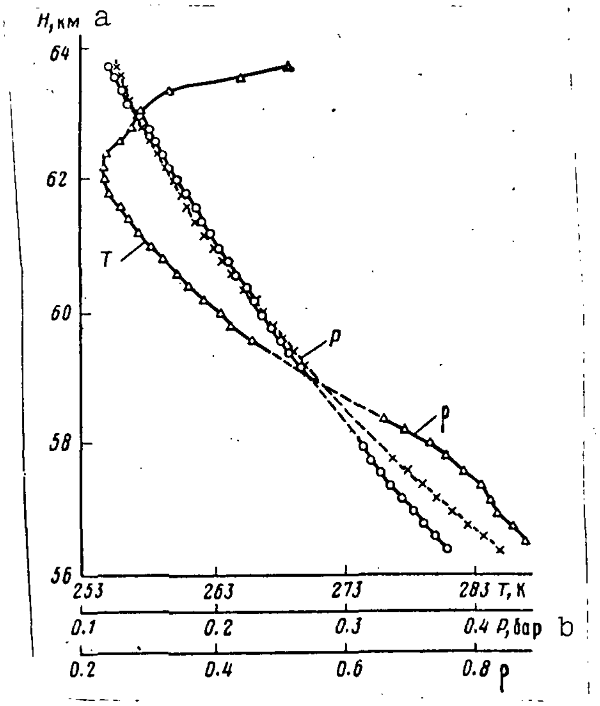

Fig. 3. Temperature inversion in upper troposphere. Density and pressure also shown
Key: a. km b. bar

reference standard voltages arrived at a 12-bit analog-to-digital converter and further, in the form of two six-bit words were fed to the memory of the "Meteo" instrument. From the memory of the instrument, the data were outputted as a serial binary file with a periodicity of 200 s to the radio complex of the lander. These data containd the absolute temperature measurements taken every 0.5 s and the relative measurements of temperature fluctuations (their analysis will be made later).

The periodicity of the pressure measurements was 0.43 s.

From the beginning of the measurements to the 2 bar level, the "Meteo" instrument released data from the P1 and P2 sensors in the form of a parallel 12-bit code. When the pressure around P2 = 2.8 bar, the "Meteo" instrument automatically switched to sending data from the P3 and P2 sensors. The P2 sensor ceased operating at a pressure of ∿30 bar; its calibration measurements pertained to the range 0-20 bar. /104

2. Results of measurements. The temperature and pressure were measured over the entire sector of the descent in the Venusian atmosphere. The measurement results are shown in Fig. 1. The measurements with both temperature sensors are in agreement everywhere to within approximately 2 °K. The small difference between their readings is regular in trend and is associated mainly with the difference in the sensor time constants, which is easily seen in the regions with a change in the temperature gradient at high lander descent rates (the measurements of the T2 sensor lagged with respect to T1). In the following, mainly measurements by the T1 sensor are presented. The results as to temperature, pressure, and altitude given in this study are preliminary, since all corrections have not yet been incorporated.

From these data, the surface temperature is 733±1 °K; pressure, 89.3± bar. Taking P_0 = 92.1 bar as the zero reference level (R_0 = = 6052 km), adopted in the Venus International Reference Temperature, VIRA (Sieff et al, 1984), we obtain the landing point altitude of 500 m. From the temperature and pressure measurements, in the hydrostatic approximation, with allowance for changes in the acceleration due to gravity with altitude and using the equation of state for carbon dioxide gas, the dependence of altitude over the landing site on time H(t) was calculated, also shown in Fig. 1. The altitude ∿63.6 km corresponds to the beginning of pressure measurements.

The plots of the temperature and pressure as functions of altitude over the landing site are shown in Fig. 2. With the exception of the upper sector, on the average their profile is in agreement with the data obtained by the "Venera" landers and by the "Pioner-Venera" probes. In the lower 12-km region, the temperature and altitude measurements have not previously been made with high accuracy. Several features of the vertical thermal structure are observed here for the first time. A strong temperature inversion at the altitudes 62-64 km was noted (Fig. 3). Here the minimum temperature directly under the inversion layer was 254 °K (at the altitude of 62 km); above this level, the temperature climbs rapidly, reaching a maximum of 269 °K at the altitude of 63.6 km. The vertical temperature profile can be clearly traced through several layers with different static stability. The boundaries between them occur at the altitudes: ∿8, ∿38, ∿45, ∿56, and ∿62 km. A near-adiabatic temperature change is observed from 45 to 56 km and for the first time in the layer to 8 km; at these altitudes thermal convection is possible. In the remaining regions, the temperature gradient is smaller than the adiabatic gradient and the stratification is stable.

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