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AN OVERVIEW OF THE SOVIET VEGA BALOON
EXPERIMENT AND STUDIES OF THE ATMOSPHERE
OF VENUS

Sagdeev, R.Z. et al.

CONTENTS

THE FIRST STAGE OF THE VEGA PROJECT

R. Z. Sagdeev and V. I. Moroz

The general data is presented pertaining to the Venus   /5*
part of the Vega mission and listing the scientific experi-
ments which were carried out on the landing modules and on
the probing balloons.

In June 1985, the landing modules of the automatic interplanetary
stations Vega 1 and Vega 2 have accomplished the soft landing on the
surface of Venus. In the course of landing, the air balloons sepa-
rated from the landing modules and were freely floating within the
Venus atmosphere for approximately two days and nights at the height
of about 54 km.

The Vega mission was designed to investigate two bodies of
the Solar System - Venus and Halley's comet. After the flight in
the vicinity of Venus and the landing module "separation" maneuver,
the automated interplanetary stations were fed the correction pulse
which placed them in the orbit, ensuring an encounter with Halley's
comet in March of 1986. The comet part of the scientific program
is a completely new one, since previously, the comets were not
studied by space means. The part of the program devoted to the
Venus study is the continuation of a lengthy cycle of investigations
of this planet, started in our country about 20 years ago. None-
theless, it also contains many new elements. The most important
of them is the first balloon within the atmosphere of another planet.

Among all planets of the Solar System, Venus resembles more
than any others the Earth in terms of a number of general parameters
(mass, size, energy absorbed from the Sun). The fact that it differs
substantially from the Earth in terms of atmospheric composition,
planetary structure and climatic parameters has not been fully ex-
plained as yet and therefore, the further investigation of this
planet remains a pertinent problem. Among the most important prob-
lems are the superrotation of the atmosphere, chemical conversions
at different heights, composition of the planetary cloud cover,
surrounding it, the history of water, possible manifestations of

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

the volcanic activity and chemical composition of the soil. The majority of these problems have been reflected in the program of scientific experiments,discharged on the landing modules and on the balloons of the Vega mission.

The balloons made it possible for the first time to observe directly the movement of the air mass within the Venus atmosphere. Several new experiments on the landing modules were aimed at the comprehensive investigation also of the physical properties of the particles found in the clouds. Let us point out that it was possible for the first time to study in detail the parameters of the aerosols and the amounts of small gaseous components on the dark side of the planet. Of great importance is the continuation of the soil com- /6 position studies, which were started on Venus 13 and Venus 14.

The project Vega is being carried out within the framework of international study - the Interkosmos program. A considerable contribution to the study of Venus (by using the Vega spacecraft) was made by the French scientists.

The attached figures show schematically the major stages of the descent of the landing module and the activation of the probing balloon. The time, coordinates, heights and other most important parameters of the mission are shown in Table 1. In terms of the /7 design, the landing module was similar to the one which was used on Venus 13 and Venus 14, and the landing maneuver also differs only slightly.

Table 2 lists the scientific experiments which were carried out on the landing module, and Table 3 - on the probing balloon. The scientific equipment on Vega 1 and Vega 2 was identical.

The reception of scientific data from the landing module was accomplished by the Soviet ground measuring stations, utilizing a number of large antennas. The terminal station and the department of scientific data processing at the Institute of Space Research, Academy of Sciences of the USSR (ISR) were generating the current updated experimental data, as it was received, and the researchers were receiving this data in the form of curves and tables, directly during the operation of the landing modules. The primary data processing and analysis of some experiments has already been finished and several more months will be required in the case of some other experiments. It is being planned in a number of cases and during somewhat later stages,to undertake the joint data processing and interpretation (the results of aerosol studies and the atmospheric gas composition).
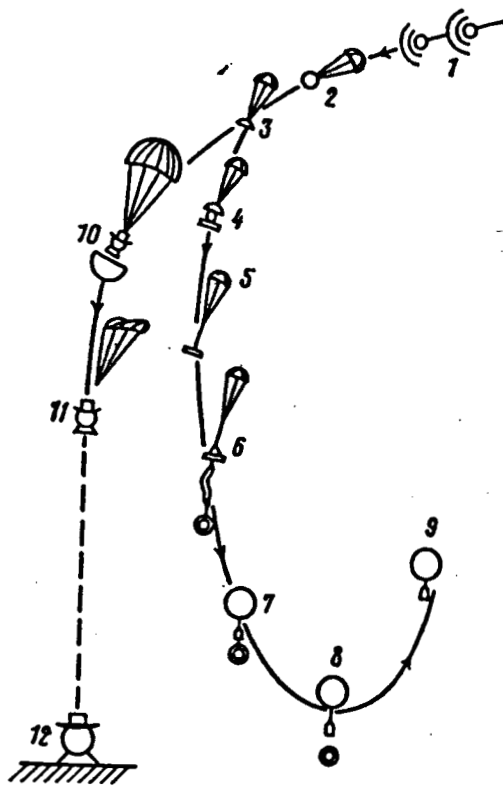
Basic stages of landing module descent and activation of the probing balloon: 1 - entry into the atmosphere; 2 - unfolding of the parachute with the removal of the upper hemisphere (the heat protection shell consists of two hemispheres); 3 - removal of the upper hemisphere; 4 - separation of the probing balloon; 5 - unfolding of the parachute, with the extension of the balloon; 6 - further extension of the balloon and filling of it; 7 - separation of the parachute, together with the filled balloon; 8 - separation of the ballast; 9 - placement of the balloon at the height of drift (~54 km); 10 - removal of the bottom hemisphere and beginning of the telemetric data transmission (~63 km); 11 - separation of the parachute; 12 - landing

In order to ensure the proper determination of the balloon's trajectories, within the Venus atmosphere and the twenty four-hour scientific data reception, two balloon radio telescope networks were established.

One of these /9 networks is of Soviet origin and has been coordinated by the Institute of Space Research, Academy of Sciences of the USSR, and other one was international and the control and coordination of it was discharged by CNES (France). The radiotelescopes form the interferometry system with the superlong base.

The articles which are published in this and in the subsequent issues of the magazine show some preliminary scientific results of the Venus studies, obtained during the first stage of the Vega project. More detailed information will be presented later in Space Research, and in other magazines.

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TABLE 1. LANDING MODULES AND BALLOONS: PARAMETERS OF TIME, COORDINATES AND OTHER DATA

Parameter	Vega 1	Vega 2
Date of takeoff	December 15, 1984	December 21, 1984
Date of landing	June 11, 1985	June 15, 1985
Moment of the parachute unfolding and beginning of telemetry data [1] reception	5 h 6 min 25 s	5 h 6 min 19 s
Moment of parachute separation	5 h 15 min 20 s	5 h 15 min 14 s
Moment of touchdown	6 h 8 min 42 s	6 h 6 min 46 s
Coordinates of landing sites:		
latitude, degrees	8.1	-7.5
longitude, degrees	176.9	179.8
Altitude at moment of parachute unfolding[2],km	63±0.5	63±0.5
Height at which the parachute has separated, km	46±0.5	46±0.5
Height at landing site, km	-0.6±0.1	+0.1±0.1
Pressure near the surface, atmospheres	95	91
Atmospheric temperature near the surface[3], K	740	734
Height at which the balloon was drifting, km	54-53	54-53
Range of active flight, km	11,500	11,000
Duration of the data transmission from the balloon, h	46	46
Pressure at the height of drift, atmospheres	0.5-0.6	0.5-0.6
Temperature at the height of drift, K	300-310	308-316

[1]Here and later, the signal reception time on the Earth is Moscow time.
[2]Here and later - with respect to the level of 6052 km.
[3]In the case of Vega 2 - on the basis of measured data, in the case of Vega 1 - on the basis of a model.

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TABLE 2. LIST OF SCIENTIFIC EXPERIMENTS AND INSTRUMENTS ON THE LANDING MODULES[1]

Name of experiment or instrument	Measured physical parameters	Nominal operational range of altitudes, km	Scientific leaders of the experiment
Meteorological assembly	Pressure and temperature	63-0	V. M. Linkin J. Blamont[2]
Doppler analysis of the carrier frequency	Wind velocity,	63-0	V. V. Kerzhanovich
Gas chromatograph Sigma-3	Chemical composition of aerosol particles and atmospheric gases	63-47	L. M. Mukhin
Mass spectrometer Malakhit	Ibid.	63-24	Yu. A. Surkov, R. Tomas[2] G. Israel[2]
UV spectrometer ISAV-S (UFS)	Chemical composition of the atmospheric gases	63-0	J. L. Bertaux[2] V. I. Moroz
Humidometer	Water content in the atmosphere	63-30	Yu. A. Surkov
X-ray fluorescence spectrometer with the particle collector IFP	Elemental composition of the aerosol particles	63-47	L. M. Mukhin
Optical analyzer of the aerosol environment ISAV-A	Concentration and the spectral size of particles, shape, coefficient of diffraction, coefficient of backscattering, tropospheric nightglow	63-30	V. I. Moroz
Spectrometer of the particle size LSA	Concentration and spectrum of the particle size	63-47	L. M. Mukhin
X-ray fluorescence spectrometer with device for soil sampling	Elemental soil composition	Surface	Yu. A. Surkov
Gamma spectrometer	Quantities of radioactive elements in the soil	"	Yu. A. Surkov
Measuring device for mechanical parameters of the soil	Soil hardness	"	A. L. Kemurdzhan

[1]V. L. Barsukov was in general charge of the scientific program of landing modules.
[2]France.

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TABLE 3. LIST OF EXPERIMENTS ON THE PROBING BALLOONS[1]

Name of the experiment or instrument	Measured physical parameters	Scientific leaders of the experiment
Measurement of the balloon position by using the radio interferometry network	Position and horizontal speed	R. Z. Sagdeev J. Blamont[2] R. Preston[2]
Measurement of the radio signal Doppler shift	Speed of drift, turbulence	V. V. Kerzhanovich
Meteorological assembly	Pressure, temperature, vertical component of of the wind velocity, illumination	V. M. Linkin J. Blamont[2]
Nephelometer	Coefficient of back-scattering	J. Blamont[2] V. M. Linkin

[1] R. Z. Sagdeev was in general charge of the scientific program of the probing balloons.

[2] France and international cooperative body CNES-for radio interferometry network.

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BALLOON EXPERIMENT OF THE VEGA PROJECT

R. Z. Sagdeev, R. S. Kremnev, V. M. Kinkin,
J. Blamont, R. Preston and A. S. Selivanov

A short history of development of Vega balloons,   /10
basic data on operations and the experiment itself, on-
board equipment and the ground network are presented.

The study of the general relationships pertaining to the cir-
culation of the atmospheres around the planets requires a large
volume of experimental data which embraces different parts of
the planet and extending in time. In spite of the fact that in
terms of dynamics of the terrestrial atmosphere we have a huge
amount of experimental material, many fundamental questions have
not been answered as yet. It is not surprising therefore that the
dynamics of the atmosphere of Venus, according to some data, is in-
comparable,in information volume, and has many unsolved questions.
Among these, the superrotation of the venus atmosphere, which is
a rapid zonal rotation of the atmosphere at all latitudes, appears
to be the most interesting phenomenon, both as a physical event and
as a factor which affects the planetary climate.

Prior to flight of the spacecraft Vega, the direct measurements
in the atmosphere were conducted by 11 Soviet landing devices of
Venera type, and by 4 American atmospheric probes. Each of these
devices was transmitting the data during a time interval on the
order of 1 hour. The flight of the balloons within the framework
of the Vega project opened up a fundamentally new stage in the
study of the dynamics of the Venus atmosphere.

The balloon stations, free-floating through the Venus atmos-
phere,make it possible to conduct measurements during several days
and nights, and it is likely that in the future it could be done during
several dozen days and nights. By drifting as a result of a regular
zonal wind, they may investigate extended regions. In addition, a
number of phenomena, important for the understanding the dynamics
of the atmosphere, can be investigated only from such drifting
balloons.

The first proposals about the use of balloons for the study
of the dynamics of Venus atmosphere were made as early as 1967 by
J. Blamont. In the time period between 1974 and 1980, in accordance
with the joint program of the Interkosmos Council of the Academy of
Sciences of the USSR and the French National Center for Space Re-
search (CNES), a technical development of the comprehensive balloon /11
station has been conducted in the USSR and in France, to monitor

the physical, chemical and meteorological data in the course of flight through the Venus cloud cover, with the transmission of this information to the Earth by means of an orbital device. The organization of this project required a seperate carrier to deliver each balloon station and each orbital device.

Upon the suggestion of R. Z. Sagdeev and V. M. Linkin, the balloon program made the next step: instead of the broadcast relay, a direct transmission of all telemetry data to the Earth was established by using a low power transmitter and high sensitivity reception centers, measuring simultaneously the coordinates and speeds of the balloons by superlong range radio interferometry. In addition, the weight of equipment on the balloon has been significantly reduced and the major part of scientific research studies has been retained.

The Interkosmos Council has approved this project, outlining the following major tasks: the study of motions on small and large scale within the time intervals up to 2 days and nights, the measurement of the turbulent thermal flows and pulses within the cloud cover and the determination of physical parameters of Venus atmosphere in the areas of the balloon flight. The design and development of the balloon station was done in the USSR.

In order to receive the telemetric information from the balloons and to measure their coordinates and speed during the whole operational time, it was necessary to establish the ground receiving stations, scattered across the whole globe. After the proposal of the Interkosmos Council, the CNES has organized and coordinated the operation of the international radiotelescope network. J. Blamont and R. Preston were the scientific leaders of the international network.

In addition to the 6 Soviet radiotelescopes, including the large antennas of 70 m in diameter in Evpatoriya and Ussuriysk and 64 m in diameter antenna in the settlement of Medvezhyi Ozera, near Moscow, the signals from the balloons were also received by 14 tracking stations abroad. Practically all the largest radiotelescopes of the world took part in this balloon experiment.

The telemetry information was received by the two largest Soviet antennas (in Evpatoriya and Ussuriysk) and three 64 m in diameter antennas of the long-range space communication network in Goldstone, USA, Madrid and Canberra.

Each balloon station of the Vega project was delivered to the Venus atmosphere, together with the landing module. The balloon shell and gondola of the station were packed within a toroidal container which was placed around the transmitting antenna of the landing device (Figure 1). On the top of this
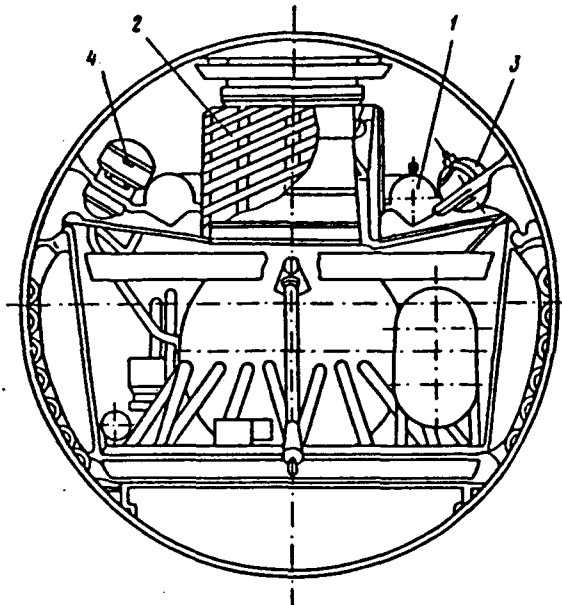
Figure 1. Placement of the balloon station equipment on the landing module: 1 - toroidal container; 2 - transmitting antenna of the landing module; 3 - helium high pressure tanks; 4 - parachute container.

Container, the high pressure tanks were mounted which supplied the helium for filling, as well as the container with the balloon parachute, the programmable timer for activation of the balloon's operation, the pyrotechnical devices and the electric power supply.

The total weight of the equipment and instruments, necessary for all operations of the balloon in the Venus atmosphere (Figure 2) together with the balloon station, was 120 kg.

Both balloon   /12
stations were placed in the Venus atmosphere on the nightside, about midnight, local time, at the point having the following coordinates:

	Latitude	Longitude
Vega 1	+8°1'	176°9'
Vega 2	-7°5'	179°8'

The balloons floating height of 53-54 km was selected within a dense cloud cover, inside of the convective zone, where the action, maintaining rapid atmospheric rotation from the east toward the west, the superrotation of the atmosphere, would be more apparent. After the activation of the balloons, they were drifting westward (Figure 3) driven by the zonal wind. The balloon stations were functional within the Venus atmosphere, 46 h each, the first one from 11 June through 13 June of 1985, and the second one - from 15 June through 17 June, 1985. Along the whole flight path the balloon stations were measuring temperature, pressure, vertical component of the wind velocity, the coefficient of backscattering, mean illumination and were tracking the change of illumination within the cloud cover. The high stability onboard oscillators made it possible to carry out the Doppler measurements and to make first evaluation of the balloon trajectories.

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Figure 2. Sequential operations of the balloon station activation: 1 - entry (H=125 km, v<11 km/s, θ=-19°); 2 - unfolding of the removal parachute (t=38 s, H=64 km); 3 - removal of the upper hemisphere (t=30 s, H=63 km); 4 - probe detachment (t=70 s, H=61 km); 5 - unfolding of the parachute for the balloon planetary injection (t=200 s, H=55 km); 6 - unfolding and filling of the balloon (t=300 s, H=54 km); 7 - separation of the balloon, together with the filling system; 8 - ballast separation, altitude adjustment (H=50 km); 9 - placement at the height of drift (t=15-25 min, H=53-54 km).

In the future, once the balloon station signal has been recorded by different radio-telescopes and processed, it will become possible to determine the wind velocity vector during each operational time period of the transmitter and to reestablish the drift trajectories in three dimensions.

According to the telemetry data and on the basis of Doppler measurements, the balloon stations flew within the Venus atmosphere about 1/3 of the planet's circumference in the latitudinal direction, with the mean velocity of 69 m/s (Vega 1) and 66 m/s (Vega 2) at the height of 53-54 km, which is close to the nominal one. The balloon stations have intersected the terminator after 34 h (Vega 1) and 32 h (Vega 2) after the injection and have finished their work on the dayside, with the solar zenith angle of about 60-55° (Figure 3). The length of the balloon station operation which was 46 h, was defined by the electric power stored in

Figure 3. Flight diagram of the balloons Vega 1 and Vega 2: Term-1 and Term-2 are the positions of the morning terminator for Vega 1 and Vega 2, the star indicates a mountain of 5 km in height and the dotted line indicates the flight around the illuminated side of Venus.

Key: 1. Ishtar Terra; 2. Term-1; 3. Term-2; 4. Vega 1; 5. Vega 2; 6. Aphrodite Terra

the power supply cells. Toward the end of operation, the mean
flight altitude of the balloons has dropped because of helium
diffusion from the balloon, by approximately 500 m. The balloon
shell with helium is being heated on the dayside by the solar
radiation, which compensates the height loss associated with the
diffusion and therefore, as it appears, the balloon station flight
has been continuing even after the signal transmission to the Earth
has terminated.

The 20 radiotelescopes of the ground network were receiving
and recording the balloon station signals from Vega 1 and Vega 2,
displaying a high signal-to-noise ratio. In the course of 4 days
and nights of the experiment a total of about 1200 recording ses-
sions were made by the radiotelescope network, with the total
amount of data recorded of $\sim 1.5 \cdot 10^{12}$ bits. It is being projected
to complete processing of the magnetic tapes toward the end of
1986, to determine the trajectories and speeds of the balloon
stations, flying through the Venus atmosphere. The preliminary
results of data processing, the methods of measurements and para-
meters of the systems are presented in the articles which are to
be found in this and in subsequent issues of this magazine.

The successful completion of the balloon experiment was
possible due to a broad international cooperation and direct
participation of many groups and organizations and several radio
astronomy observatories. The authors extend to all of them the
most sincere gratitude.

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VEGA BALLOON EXPERIMENT: THE GROUND NETWORK

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and V. V. Kerzhanovich

A special ground network was created to conduct
the interferometry measurements on the Vega balloon
stations and to receive the meteorological information.
Practically all the largest radiotelescopes of the
world were involved, forming a unique global inter-
ferometry network at 18 cm wavelength.

The major task of the balloon experiment in the Vega project
was to study the dynamics of Venus atmosphere. The proposal to
study the general circulation of Venus atmosphere by using a
probing balloon with a radio transmitter on it, and having an
interferential network on the ground, was made in April 1974, at
the Symposium EOS-Venera, in Moscow (Kogan et al., 1974). It was
necessary to measure the balloon trajectory at a distance of more
than 10^8 km with the accuracy of about 1-2 m/s, in terms of speed
and 10-20 km, in terms of coordinates. As a method for measure-
ments, it was proposed to use the very long base interferometry
(Matveenko et al., 1965). This method has acquired a wide utili-
zation not only in radio astronomy, but also for the solution of
many applied problems, including the problems of spacecraft navi-
gation (see the review by Matveenko, 1977). At the present time,
many large radiotelescopes of the world, including the 22 m radio-
telescope in the Crimea, are forming a unified global instrument
(Kellerman et al., 1971). The regular studies of faint signals
from the radio sources are being conducted regularly, with the
determination of relative position of specific components, within
a broad range of the wavelength.

To handle the problems of the balloon experiment, the existing
network was significantly expanded, taking into account the need for
a continuous, around-the-clock observation. Of fundamental im-
portance was the development of the network across the whole terri-
tory of our country, which has significantly expanded the capa-
bilities of measurements, providing the around-the-clock measure-
ment of the balloon trajectory. The network was developed on the
basis of radiotelescopes in Evpatoriya, Ussuriysk, Medvezhyi Ozera
(near Moscow), Simeize, Ulan-Ude, Pushchino. Of great importance
became the involvement of the NASA long range space communication
stations (Goldstone, Madrid, Canberra), which had at their disposal
the high sensitivity antennas. As one can see, the balloon experi-
ment unified practically all large radiotelescopes of the world into
a single radio interferential network, combining the efforts of the

experts in all the leading countries of the world. The international radiotelescope network and its operation was coordinated by the French Center for Space Research (CNES).

The selection of wavelength was determined by a number of factors, sometimes contradictory. It was necessary first of all to design a highly stable, small-size on-board transmitter and this has predetermined the selection of the decimeter wavelength range. On the other hand, taking into account the short time and high cost of the equipment assemblies on the ground, one has to select the range which has been mastered well. As has been noted earlier, the radio astronomers had at their disposal an extensive radio interferometry network, operating in the decimeter range, at the 18 cm wavelength. This range is practically free of industrial noise. The effect of ionosphere and of the interplanetary environment, as they relate to the accuracy of measurement, was relatively speaking, negligibly small in this range. And finally, one has at one's disposal at this wavelength sufficiently powerful sources of maser radiation, which emit the narrow hydroxyl lines. These sources make it possible to adjust and check out the systems in the conditions approximating the operational conditions (the radiation measurements within a narrow band of the balloon transmitter). By using the same sources, one can very simply carry out the preliminary check out of the network and tie-in the time and observation points. The final network adjustment is done by using quasars which, at this wavelength, are sufficiently intense.

The "intrusion" into the radio astronomy range was not as dangerous as it might appear at first glance. The experiment was of astrophysical nature and was conducted with the participation of the radio astronomers themselves, and the power outputs of the transmitter on the balloon and on the detachable device are so small (5 W) that they can be detected only after a special, narrow band processing, and even then under the conditions that the antenna is aimed at the space device and is of substantial size. On the other hand, the radio astronomers were able to do their research in this range by using the radiotelescopes of high sensitivity. And finally, getting ahead of ourselves, one might say that this joint cooperative work facilitates the development of the radio interferential network on the ground and the design of space interferometer assembly which is being developed by the joint efforts of the scientists in many countries of the world.

The development of extensive interferential network, including the interferometers with bases of different length and orientation makes it possible to exclude the ambiguities in the coordinate measurements by interferential method. With the same purpose in mind, the balloon and the space device itself were regularly emitting two side frequencies, separated by 6.5 MHz (Kremnev et al., 1986).

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On the majority of stations, the basis for the equipment within the radio interferometer assembly was the system of MARK 2 type. The utilization of two sets of conversion systems made it possible to switch the received frequencies to 0.4, 1.4 and 1.8 MHz frequencies and after filtering, to record them on video magnetic tape. In order to improve the signal reliability and to decrease losses during the digital processing of weak monochromatic signals, a number of Soviet stations had developed a special equipment for the reception and /18 recording of Vega signals (Armand et al., 1986).

Several articles in this and subsequent issues of the magazine will be devoted to the description of the methods used in measurements, to the networks of the ground stations and the methods of signal processing within the framework of the balloon experiment.

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VEGA BALLOON AS A TOOL TO STUDY THE DYNAMICS
OF THE VENUS ATMOSPHERE

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The balloon and meteoroligical sensors of the Vega   /19
station are described. The operational cyclogram is
presented and the specific features of the meteorological
data transmission and transformation are given.

The balloon mission of the project Venera- Halley's comet (Vega)
provided for the injection of two balloons into the Venus atmos-
phere to investigate its parameters along the drift trajectory, at
the height of the floating balloons. The major tasks of this ex-
periment were to track by the on-the-ground radio technical means
the horizontal movement of the balloons which would reflect the
direction and speed of the wind, and to measure directly the atmos-
pheric parameters by using the gondola probes for the study of the
local structure of the atmosphere, the variation in the density of
the cloud cover, the changes in illumination and to record some
possible light phenomena. The balloon itself, the gondola with
sensors and the radio assembly, together with the radiotelescope
network on the ground, were used as the measuring means within the
framework of the balloon experiment.

The balloon itself was essentially a closed spherical pres-
surized cell, made of teflon fiber and coated with a teflon film.
The diameter of the shell, filled with helium up to the nominal
excess pressure of 30 mbar, was 3.4 m. The total weight of the
balloon was 21 kg, of which 12.5 kg was the weight of the shell
itself, with all junctions and attachments, 2.0 kg was the weight   /20
of the helium and 6.5 kg was the weight of the instrumental gondola.
The balloon was designed in such a way that it would float at the
nominal altitudes on the order of 53-54 km within the Venus atmos-
phere. The total volume of the shell was 19.6 m^3 with zero excess
pressure. The increase of excess pressure within the shell by 10
mbar results in the increase of the shell volume, on the average,
by 1.0 m^3. As the tests have shown the helium diffusion rate
through the shell is sufficiently low, so that the excess pressure
within the shell can be maintained during the period of five days
during the simulated flight procedures in the Venus atmosphere.

The gondola was of about 1.2 m in length and was suspended under the shell by a 13 m long cable (Figure 1). The upper part of the gondola   37 cm in length is essentially a cone spiral antenna of 14 cm diameter. Below it, and also suspended on the cables, the two other gondola sections were attached: the transmitter, the programmed time device, master oscillator and the meteorological assembly "Meteo" (telemetry equipment, pressure and illumination sensors, collapsible rod on which the temperature and vertical wind velocity sensors are mounted). The lower gondola section contained the cloud cover density probe - the backscatter nephelometer and the power supply cells for all systems of the balloon. The dimensions of the central and lower parts of the gondola were 40.8x14.5x13.0 cm and 9.0x14.5x15.0 cm, respectively. All external gondola surfaces were coated with a special film for the protection from the Venus atmosphere and from increased albedo.
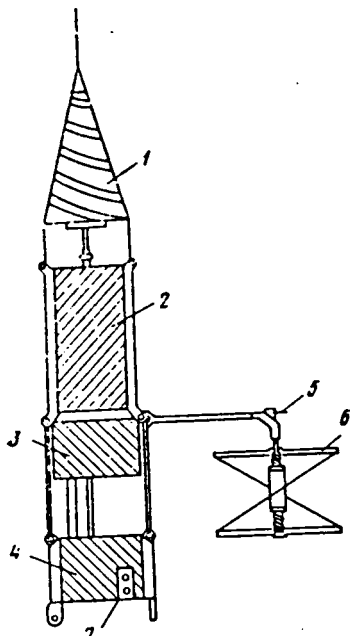
Figure 1. Balloon gondola:
1 - antenna, 2 - transmitter,
3 - meteorological assembly,
pressure and illumination
sensors, 4 - power cells,
5 - temperature probe,
6 - sensor for vertical
wind velocity, 7 - nephel-
ometer.

The balloon radio transmitter had two operational modes: the transmission of telemetry data (TM mode) and the coordinate measurements mode (CM mode is the transmission of two carrier frequencies which differ by 6.5 MHz). The TM mode commences with the transmission during 30 s of the clean carrier frequency, necessary for the interferometry and Doppler measurements and then, in the course of $\sim$270 s, the telemetry data, collected by the sensors during the preceding 30 min, was transmitted. The total duration of the operational session was 332 s. The CM mode was used to measure the coordinates and speed of the balloon by the method of differential radio interferometry with large base.

The activation periodicity of the pressure, temperature, vertical /21 wind velocity and nephelometer sensors was 75 s, and that of the illumination sensor (the mean illumination, the recorded light flashes) - 10 min. The sequence

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of TM and CM operational modes is shown in Figure 2. During the
first 10 hours of the balloon flight, from the 24th through the
36th hour of flight, every 2 hours and every 30 minutes, three
operational TM sessions were activated and one CM session. From
the 12th through the 24th hour, and from the 36th through the end
of the operation, every 2 hours, after 60 min, the operational TM and
CM sessions were activated. The signal carrier frequency was
1667.9 MHz.

At the same frequency and simultaneously with the balloon
signals, the signals from the Vega spacecraft, necessary for cor-
rection of the effect of interplanetary environment, of the iono-
sphere and of the atmosphere, were also transmitted. The frequencies
of these signals as received on the ground were different because
of the difference in the speed of motion of the sources.

The transmitter power output was about 4.5 W. As the balloon
was moving along the Venus circumference, the effective emitted
power toward the Earth was changing from 2 to 4.5 W because of the
angle variation between the local vertical, the balloon antenna
and direction toward the Earth. The balloon shell is radio trans-
parent. The antenna gain factor, including all loses, was ≈ 0.5,
with an 80° deflection from the antenna axis and ~1.1 along the
antenna axis. The on-board stability of the master oscillator
was $\Delta f/f \sim 5 \cdot 10^{-11}$, making it possible to accumulate the signal
coherently on the ground during several seconds.

The balloon power supply which is located in the lower part
of the gondola, consists of a set of lithium cells, with a total
weight of 1 kg, and the practical electrical capacitance of 250
W·h. The projected operational time of the power supply, based
on the preflight test of the whole gondola, was 46-52 h.

The gondola instrumental section of each balloon station in-
cluded the block of electronic equipment, the sensors for pres-
sure, temperature, vertical component of the wind velocity (anemo-
meter), illumination and the light flashes, as well as the back-
scatter nephelometer.

The pressure sensor, set up in the meteorological assembly
for the measurement of the surrounding pressure, had in its air-
tight enclosure a special input. The pressure sensor was essentially
a quartz resonator, connected into the master frequency circuitry of
the oscillator. The resonance frequency of the quartz device is a
function of mechanical tension, caused by the external pressure.
The absolute accuracy of this sensor was on the order of 0.5 mbar,
with the resolution of about 0.2 mbar across the whole dynamic
range, from 0 to 2 bar. The dependence of the sensor output
frequency on temperature was very slight. Nonetheless, it was
taken into account during the processing of measured data.
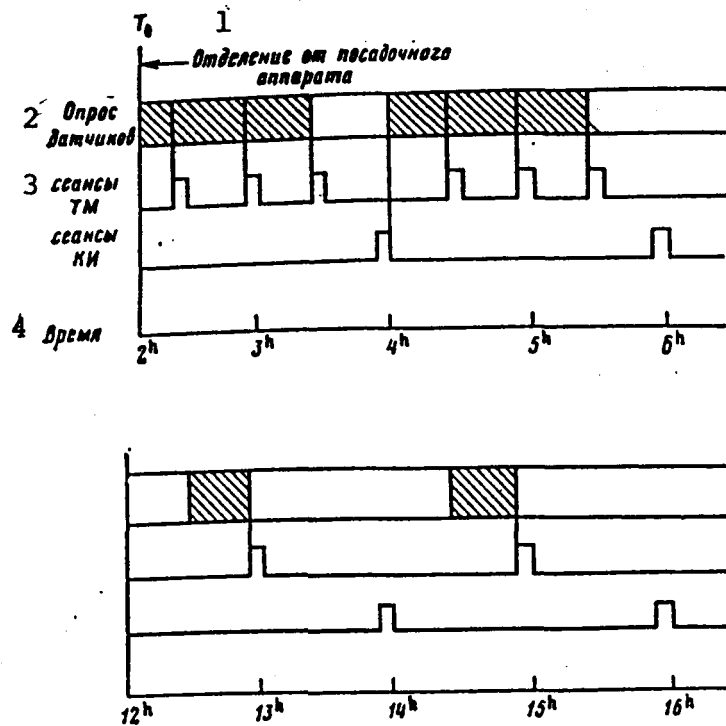
Figure 2. Operational cyclogram of the balloon
(time - from the moment of operational injection).

Key: 1. Separation from the landing module;
2. Operational requests, addressed at the sensors;
3 - TM and CM operational sessions; 4 - Time

The temperature sensor was mounted on a special rod which,
after the descent of the gondola, was extending in the horizontal
direction. The sensor was essentially the metal film resistance
thermometer, applied to a flexible dielectric substrate of 20 μm
thickness and 1.0 x 1.0 cm size. Each side of the sensor was
shielded by dielectric coating of 1 μm in thickness. The sensor
at normal conditions has the impedance of about 35 ohm, including
the bridge, and the reference resistor. The temperature sensor
was connected by means of an electronic switch, the the twelve-
digit analog-to-digital converter (ADC). The sensor calibration
had shown that its absolute accuracy is 0.5 K, with the resolution
of 0.1 K, in the range between 263 and 353 K. The sensor time con-
stant is not more than several seconds with the relative speed of
the airflows of about several meters per second.

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To measure the atmospheric flows with respect to the gondola axis (which is nominally vertical) a special fan anemometer was designed. The anemometer includes one unfolding fan, suspended at the end of the external rod at a distance of 24 cm from the meteorological assembly. Prior to the activation of the balloon, the anemometer was packed together with the rod and once the rod was extended, the anemometer was automatically opening, utilizing the mechanical spring-loaded devices. The anemometer fan assembly has two separate fans with four blades each, with the extended wings between them, made of three-layered film spiral (polyethylene-Malar-polyethylene). Both fans are mounted on a ball bearing-supported rotor, the rpm of which, and rotational directions, are recorded by two pairs of light and photo diodes, separated by the rotating disk with perforations. The rpm and direction of rotation was recorded every 75 seconds.

The activation threshold of the anemometer fan assembly was /23 ~0.25 m/s. In conjunction with the fact that the anemometer signal recording was conducted by using the six-digit words, the maximum speed of the flow which could be recorded before the counter would overflow, with the appearance because of this of some ambiguity, was about 1.5 m/s. At higher speeds, this uncertainty could be removed in the majority of cases by taking into account the dynamics of the balloon motion and the measured pressures. After the flow was terminated, the time before the rotor would completely stop was several seconds. The sensitivity with respect to the horizontal wind was negligibly small.

The actual vertical wind velocity was obtained on the basis of the measured rpm of the fan, taking into account the preliminary laboratory calibration of the anemometer, the pressure data and modelled balloon motion.

The light detector which was used to measure the total illumination and the light flashes was essentially a silicon PIN diode, located below the meteorological assembly, in the central part of the gondola, receiving the radiation from below, via a cone, at an angle of $\pm 60^{\circ}$. The detector sensitivity lies in the spectral range between 400 and 1100 nm. The detector signal output was fed first to a preamplifier and then to ADC. To measure the light flashes, the signal from the detector, after the preamplifier, would be fed to three comparators and counters, the dynamic range of which was about 70. Although the balloon block of electronics utilized the twelve-digit converter, in converting the signal associated with the flashes and illumination, only six less significant digits were used which were transmitted twice during each 30-minute telemetry time period, making it possible to record the changes in the illumination level.

In recording the light flashes, the counters were calculating the number of events, when the light signal from the preamplifier would exceed the threshold of one of three comparators, which have been set up in such a way that the signal level, necessary to switch over to the next comparator, would have a higher level by a factor of three.

The number of events of the lowest of the three levels were recorded by the four-digit counter, and to record the flashes at the two upper levels, two single-digit counters were used. As a result, the light flashes data was contained within the six-digit word and was transmitted three times per frame.

The cloud cover density probe was essentially the backscatter nephelometer which is similar in principle to those which were mounted on-board of Pioneer probing devices, and on the previous Venus landing modules. It consisted of the pulse light source made of gallium arsenide with the emission at 930 nm, the silicon PIN diode with the solar protection filter-detector, corresponding to the optics of the emitter and receiver and the electron device which was necessary to record and enhance the signal and to obtain the emitter pulses of the needed amplitude and duration. Each nephelometer enclosure mounts the temperature sensor which records the instrumental temperature and also a special device for the in- /24 strumental zero adjustment.

The nephelometer calibration and testing had shown that the absolute instrumental accuracy was about 10^{-5} $m^{-1} \cdot sr^{-1}$ and that the changes on the order of $2 \cdot 10^{-6}$ $m^{-1} \cdot sr^{-1}$ may be accounted for as the backscatter signal passes through the instrument.

The nephelometer was a unit of 2.0 x 5.5 x 6.5 cm size, located within the enclosure of the balloon power supply, in which two openings were made for the emitter and for the transmitter. The nephelometer sensitivity range was from 4 cm to 1 m from the lateral wall of the power supply enclosure.

Figure 2 shows the time diagram which indicates the sequence of the data transmission. Each telemetry frame included the data volume, consisting of 852 bits, recorded into the memory, on the basis of the sensor readings of the balloon during the preceding 30 min, and also the synchronous service word, 48 bits long. The data flow was transmitted with the rate of 4 bits per second during the first 840 bits and then the subsequent 60 bits were transmitted at the rate of 1 bit per second.

The measurement of specific parameters within the forming data flow was conducted in the following manner. The pressure was represented with the accuracy of 12 digits and the 6 most significant

b i t s were transmitted only three times within each telemetry
frame, and the 6 less significant bits - 21 times. The telemetry
frame was presenting in an analogous fashion the temperature where
the 6 least significant bits were transmitted 19 times and the
most significant bits - 3 times. The two six-digit words within
the temperature sensor data flow were reserved for the transmission
of the illumination sensor data.

The nephelometer data which was represented by the twelve-digit
words has been transmitted 19 times during each telemetry frame
transmission. In addition, two twelve-digit words were allocated
for the transmission of the temperature readings inside of the
nephelometer unit, and two were reserved for the transmission of
the nephelometer zero reading. The six-digit words of the vertical
wind velocity component were transmitted 21 times. Three words
were reserved for the transmission of the data from the illumination
sensor and light flashes.

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VEGA BALLOON EXPERIMENT: THE GLOBAL NETWORK OF RADIO-TELESCOPES AND FIRST RESULTS

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A unique network of 20 radiotelescopes was formed   /25
to provide 24-hour telemetry aquisition and trajectory
measurements of Vega balloons. Differential very-long
base radio interferometry was used to determine trajec-
tory of the balloons. First results from Doppler data
allowed to estimate mean zonal wind velocity and to find
an anomaly in Vega 2 trajectory as it flew over the
mountains of Aphrodite Terra.

The balloon stations Vega made it possible for the first
time to carry out some lengthy studies of the dynamics of the
Venus cloud cover. The information about the balloon movements
obtained by using the radiotelescope network on the ground, after
proper processing, will produce a detailed picture of the mean
zonal flow change, of large-scale vortex movements, the wave
processes, and by combining the data with the meteorological
measurements on-board of the gondola, will describe the tur-
bulence, the momentum quantity of motion and heat which has been
transmitted and the meridional movements. At this point, the data
of Doppler measurements are the very first results. The radio
interferometry data will require much more lengthy processing.

The radio interferometry makes it possible to determine in
each instance the two components of the velocity vector and the
balloon position, in the plane perpendicular to the sighting line
Earth-Venus. The third components are determined on the basis of
the meteorological and Doppler measurements. At least three
antennas must simultaneously receive the signal from the balloon /26
and from the spacecraft. The method of determining the balloon
speed was analogous to the one used during Pioneer-Venus probing
(C. Counselman et al., 1980). By using the radio interferometry
technology with very-long bases it is possible to obtain the
lateral (with respect to the sighting line) velocity components,
by subtracting the frequency of signals received by the antennas
which were at a great distance. The errors caused by instability
of the on-board master oscillator will decrease significantly by

using such subtraction. By using one pair of antennas, it is possible to determine the lateral velocity component in the projected direction of the base (a straight line connecting the phase centers of the antenna) toward the landscape plane (the plane which passes through the center of Venus, perpendicular to the sighting line). In order to determine the two lateral components, one must always have three antennas.

The balloon speed was determined during the operational sessions of telemetry transmission, when just one carrier frequency is being emitted (Kremnev et al., 1986), as well as during the CM (coordinate measurements) operational sessions, when two carrier frequencies are emitted from the balloon, spaced by 6.5 MHz.

The method of determining the balloon lateral coordinates is similar to the differentiated radio interferometry method which is used to navigate the interplanetary spacecraft. The coordinates may be determined by measuring the phase difference between two coherent carrier frequencies during the CM sessions. By obtaining the phase difference between two carrier frequencies at each station and then by subtracting these differences from two antennas, it is possible to determine the range difference and consequently, the angular position of the balloon with respect to the base line. To determine the two components of the balloon position, it is also necessary to receive the signal simultaneously by three antennas, forming a triangle. The ambiguity in determining the position (because of the ambiguity in 2π which is used for phase determination) may be resolved on the basis of the a priori data as to the position of the balloon, and also on the basis of interferometry measurements by using short bases. The determination of balloon coordinates is important in order to obtain the optimal estimates of the long-term atmospheric movement, tying it with the meteorological measurements.

The simultaneous signal reception from the balloon and from the spacecraft makes it possible, during the subsequent subraction, to exclude for all practical purposes, the effect of any common error such as, for example, the differences of the clock readings at the stations, the errors in the knowledge of the vector base, the errors because of the troposphere effect, the effect of the ionosphere and of the interplanetary plasma. In this case, the balloon coordinates are determined with respect to the spacecraft trajectory, which has been measured independently. The essence of the differentiated radio interferometry method is based on such subtraction (C. Counselman et al., 1972).

The spacecraft trajectory was determined by using the coherent Doppler measurements of speed and range by the Soviet network and also by the routine, automatic Doppler and interferometry

readings, made by NASA DSN during several weeks, prior to and after the Venus flight. To increase the accuracy of the DSN network, the position of the spacecraft was also determined by differential method with respect to quasars.

The third component of the balloon velocity - the vertical one, is determined on the basis of the on-board temperature and pressure measurements. The balloon velocity data, as projected toward the sighting line was obtained by using Doppler measurements. The balloon altitude was determined on the basis of pressure measurements.
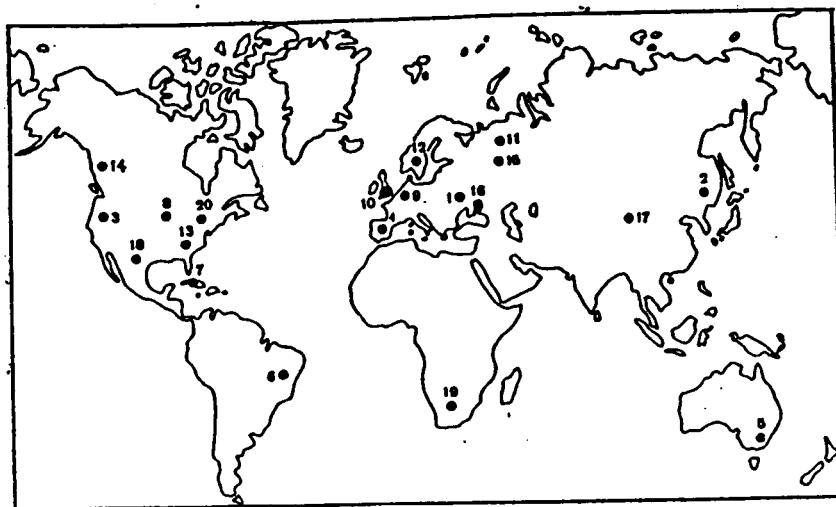
Figure 1. Global network of the radiotelescopes which were involved in the balloon experiment (the numbers of the stations correspond to the numbers in Table 1).

Because of instability of the on-board master oscillator, the time of coherent signal accumulation is not more than several seconds. Therefore, in order to receive a weak signal from the balloon and to provide coherent measurement during the time of ~1 s and less, it is necessary to receive the signal from at least one of the large antennas (major receiving stations). The utilization of the signal phase change from the major stations allows for more time for coherent accumulation (comparable with the length of the communication session which is equal to ~330 s) at the small receiving stations. The "major" stations which were used are in Evpatoriya, Ussuriysk, Goldstone, Madrid and Canberra.

The position of twenty radiotelescopes within the global network which were tracking the balloons is shown in Figure 1. The antenna diameters are shown in Table 1. The global network made it possible to carry out almost 24-hour measurements at least at two

large orthogonal bases (with the exception of the time interval of about 2 hours above the Pacific ocean). The global network had an excess number of radiotelescopes, which improved the reliability of the signal reception. The data of preliminary processing has shown that the signals were received in a normal fashion by all antennas.

The ground observatories were utilizing primarily standard equipment for radio interferometry measurements, to record the signals from the balloons and from the spacecraft and the equipment was of MARK 2 type. Since its recording band is 2 MHz, it /28 was necessary to filter individually the signal carrier in TM (telemetry mode) mode and the two carrier frequencies in CM mode, switching them toward one band of 2 MHz. The four Soviet stations were utilizing additionally some specialized system for the signal recording (Armand et al., 1986).

The transmitters of the balloon and of the spacecraft were operating at the same frequency and the frequency difference of the signals received was based primarily on the Doppler shift, comprising 10-30 kHz. In the equipment on the ground, both signals were passing through the same circuitry. The transmission from the spacecraft was synchronized by the command from the Earth in such a fashion that the middle part of the CM transmission from the spacecraft would coincide with the balloon CM sessions.

Table 2 shows the estimates of major errors which contribute to the errors in determining the coordinates and speed of the balloons. It is expected that the root-mean-square errors in determining the balloon coordinates and speed will be 15 km and 1 m/s, respectively. The major factor which limits the accuracy of determining the lateral speed is the interplanetary plasma. This source of errors fluctuates quite strongly and is difficult to evaluate. However, on the basis of the measurements taken by the space devices and on the basis of the quasar interferometry measurements, /29 as well as on the basis of theoretical estimates, the expected mean error will be 0.6 m/s.

At the present time, the Doppler measurement data, obtained from the "major" stations has been predominantly processed. Within the overlapping ranges, the measurements obtained at different stations agree with the accuracy better than 1 Hz. On the basis of such data in the model of purely zonal motion, the obtained average wind velocity was 69±1 m/s for Vega 1 and 66±1 m/s for Vega 2. The estimates of balloon trajectories were also made. It was also possible to obtain the data for the small-scale turbulence within the Venus atmosphere (for greater detail, see the article by Preston et al. (1985) by Andreev et al. (1986), and by Kerzhanovich et al. (1986)). The recording of signals

TABLE 1. GLOBAL NETWORK OF THE STATIONS IN BALLOON EXPERIMENT

No.	Station	Antenna diameter, m	No.	Station	Antenna diameter, m
1	Evpatoriya	70	11	Medvezhyi Ozera	64
2	Ussuriysk	70	12	Uppsala	26
3	Goldstone	64	13	Owensville	40
4	Madrid	64	14	Penticton	26
5	Canberra	64	15	Pushchino	22
6	Atibaia	14	16	Simeize	22
7	Arecibo	305	17	Ulan-Ude	25
8	Iowa	18	18	Fort Davis	26
9	Bonn	100	19	Hart RAO	26
10	Jodrell Bank	76	20	Haystack	37

TABLE 2. MAJOR ERROR COMPONENTS IN DETERMINING THE LATERAL COMPONENTS OF SPEED AND COORDINATES (FOR 64 ANTENNAS, THE BASE LINE 6000 km)

Source of errors	$\sigma\Delta\tau$, cm	$\sigma\Delta f$, Hz	σr, km	σv, m/s
Fluctuating noise	12	$1.5\cdot10^{-5}$	2	0.04
Phase instability	36	−	6	−
Interplanetary plasma	−	$3\cdot10^{-4}$	−	1
Trajectory of the delivery spacecraft	−	−	10	0.5

Note. The noise component is for the integration time of 330 s;
$\sigma\Delta\tau$ is the error in measuring the range difference;
$\sigma\Delta f$ is the error in measuring the frequency difference;
Δr is the error in determining the position;
Δv is the error in determining the speed.

Figure 2. Difference between
measured and calculated
Doppler velocity during the
Vega 2 balloon flight above
the Aphrodite Terra. On
x axis we have time, calculated
from 0 hour on June 15, 1985 (UT).

Key: 1. m/s
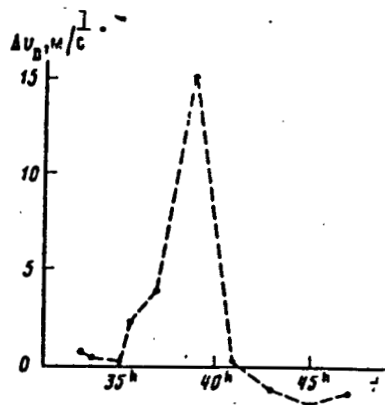
by using the international network
made it possible to carry out the
Doppler measurements and provide
the data reception during the
"great event" on Vega 2 (Figure 2).

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METEOROLOGICAL MEASUREMENTS OF VEGA 1 AND VEGA 2 BALLOONS ALONG THEIR TRAJECTORIES

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The direct measurements of pressure, temperature   /30
and relative vertical wind velocity with respect to the
Vega balloon were conducted, and the coefficient of back-
scattering from cloud particles and the light illumination
level were determined. Estimates of velocities of atmos-
pheric motion were obtained from the Doppler data.

In the course of their flight through Venus atmosphere, the balloons Vega 1 and Vega 2 were measuring the ambient pressure and temperature, the vertical wind velocity component (with respect to the gondola) the coefficient of backscattering from the cloud cover, the average level of the light illumination, the number of light flashes and time of their appearance. In addition, the ground radio-telescope network was measuring the coordinates and drift speed of the balloons by differential radio interferometry with very-long base (this data has not been processed as yet).

The zonal component of wind velocity was determined on the basis of the balloon Doppler signal frequency shifts. All these parameters were measured during the 46-hour flight of each balloon, as they drifted in a westerly direction, approximately parallel to the equator, being driven by the wind. The local time of the point of the balloon injection was near midnight and the termination of the job took place on the daylight hemisphere at a distance of $30-35^{\circ}$, once the morning terminator was passed.

Figures 1 and 2 show the ambient parameters as measured on board the gondola during the whole flight by each balloon, as a function of time.

The figures reflect the cyclogram of measurements and oper-   /32
ational sessions of the transmission to the Earth. During 46
operational hours, from each balloon station, the telemetric
data which has been collected was distributed along the drift
trajectory at either 1.5 h or 30 min intervals and the total
duration of reception was 22 h 30 min.
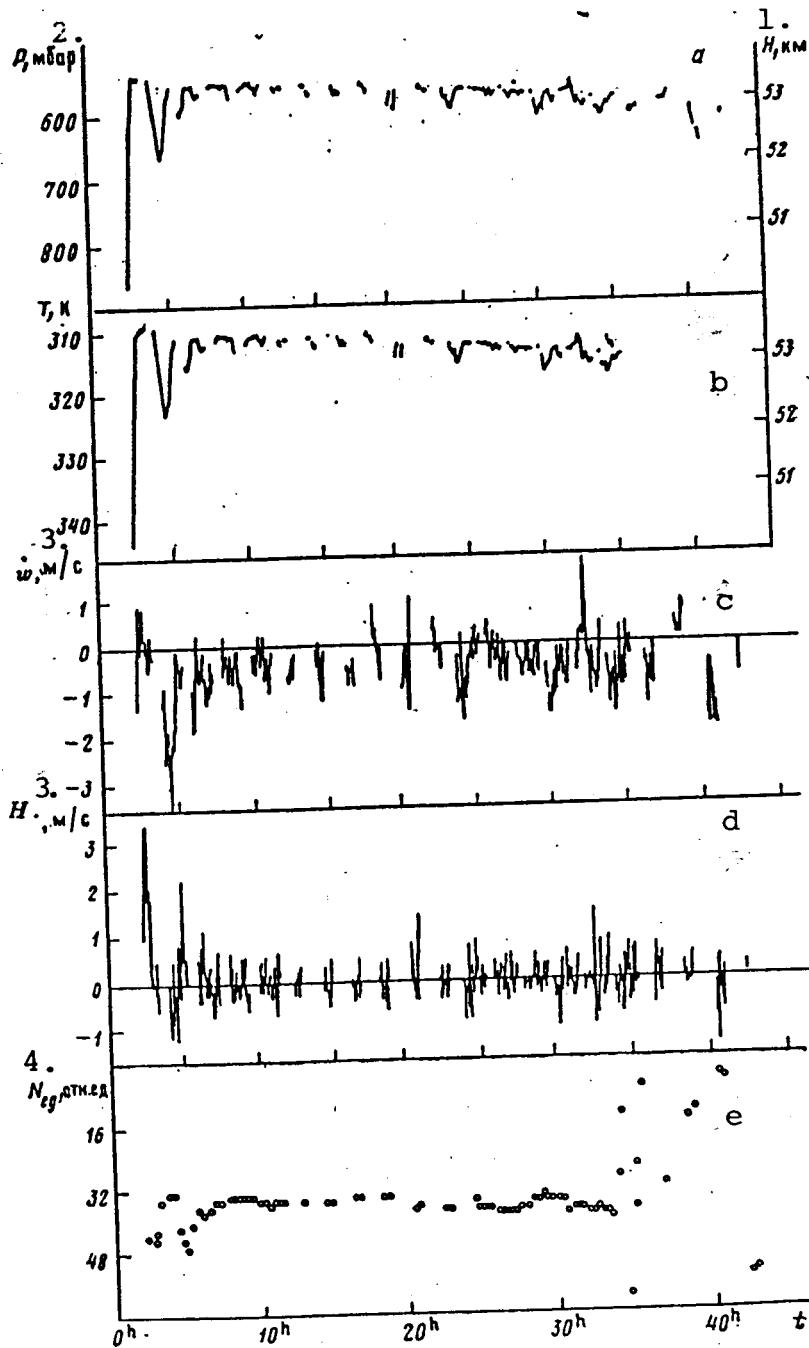
Figure 1. Meterological measurements of Vega 1: a - pressure, b - temperature, c - vertical wind velocity, d - vertical speed of the balloon, e - light sensor count. The time is counted from 0 hour on June 11, 1985 (UT).

Key: 1. H, km; 2. mbar; 3. m/s; 4. N_{eg}, relative units
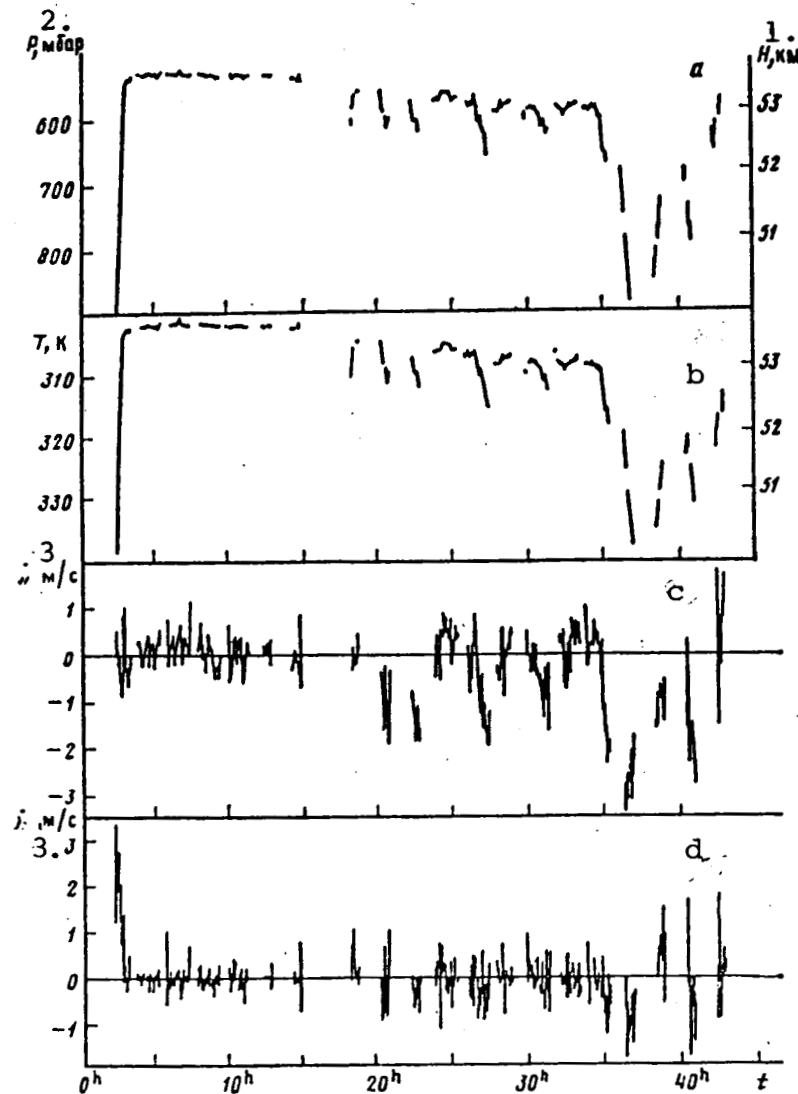
Figure 2. Meteorological measurements of Vega 2: a - pressure, b - temperature, c - vertical wind velocity, d - vertical speed of the balloon. The time is counted from 0 hour of June 15, 1985 (UT).

Key: 1. H, km; 2. P,mbar; 3. m/s

As one can see by comparing the curves in Figures 1 and 2, a and b, the pressure and temperature variation is strongly correlated. This speaks of the fact that they are due to the balloon movement in terms of the altitude and also that the temperature changes are not distorted because of the presence of the gondola and the balloon itself. The minimal temperature and pressure variation which may be /33 taken into account by calculating the correlation $\delta T=0.1$ K, $\Delta P=0.1$ mbar, show a good sensitivity and stability of the electronics and of the sensors.

After dropping the ballast at the height of about 50 km
(900 mbar) both balloons have surged up to the average ceiling of
about 53 km (535 mbar). At this point in time the excess pressure
within the balloons was about 28 mbar (on the basis of preflight
measurements). The excess pressure was retained during the whole
flight of the Vega 1 balloon, and during the first 32 h of the
Vega 2 balloon. Their floating ceiling was gradually decreasing
from ≈535 and to ≈620 mbar toward the end of the second day of drift,
because of slow helium loss. On the basis of telemetric data it was
possible to determine the initial weight of the helium within each
shell and the rate of helium loss by using the measurements at zero
vertical component of the relative wind velocity (lower than the
sensitivity threshold of the anemometer). During the flight, each
balloon lost less than 0.5% of the initial amount of helium (2.1 kg).
This figure is close to the nominal one, obtained on the basis of
preflight measurements of the helium diffusion rate through the
balloon shell and therefore, the possibility of appreciable losses
through the microcracks in the shell is excluded.

A large number of altitude changes from the equilibrated
altitude has been noted during the flight of both balloon stations.
These are due to the vertical atmospheric movements. The change
of the floating altitude is shown in Figures 1 and 2, curve d and
the corresponding vertical speeds of the balloons - on the curves
c. The amplitude of the vertical movements and speed turn out to
be considerably greater than expected. The balloon Vega 1, during
its operation, went through several extensive vertical motions and
the largest deflection from the equilibrated height took place
during the first few hours of its flight. The flight of the Vega 2
balloon was uneventful during the first 20 h, with the amplitudes of
vertical motions on the order of 100 m. Then its motion has changed
and became similar to the motion of Vega 1 balloon. In the region
of the morning terminator, in 34 h after the balloon activation,
Vega 2 has descended several times to the level of about 900 mbar.
The calculations which took into account the preflight measurements
indicate that during such drops, the excess pressure within the
shell becomes equal to zero, below 650 mbar. However, on the basis
of telemetry data received on the Earth during the last operational
session, the Vega 2 balloon has returned to its equilibrated floating
height.

The loss of excess pressure within the shell during extensive
altitude drops affects quite appreciably the reaction of the balloon
to the vertical wind gusts. As long as the shell has excess pressure
inside, the amplitude of vertical deflections from the equilibrated
floating height is proportional to the vertical component of wind
velocity (for the long-term perturbations). With the loss of excess
pressure, the balloon approaches the boundary of stable floating
and the amplitude of vertical movements greatly increases. This
effect is quite noticeable by comparing the curves a and c in Figure /34
2. To decrease the floating height by the quantity which would

correspond to the pressure change of 100 mbar, the vertical wind of 3 m/s would be required and in the presence of the vertical wind of 4 m/s, the altitude drop increases by a factor of 3.

The vertical component of the relative wind velocity was measured directly on board of the gondola. In order to obtain the vertical component of the atmospheric wind velocity, the movement of the balloon itself was taken into account by measuring the pressure change. Because of the fact that prior to the Vega balloon flight, it was assumed that there are no strong vertical winds, the anemomoter telemetric readings were ambiguous and the ambiguity occurred every 1.35 m/s (Kremnev et al., 1986). To define the ambiguity, the model of the balloon motion was used.

The results of the light or illumination sensor readings are shown in Figure 1, e. In the case of the Vega 2 balloon, this data has not been analyzed as yet. The ambient light sensor was designed to record the variation in the external radiation flow within the range from 400-1100 nm as a characteristic of the cloud cover homogeneity for the determination of time when the morning terminator has been intersected and for the determination of the duration of dawn. The same detector was used to record rapid changes in the level of illumination.

Curve 1,e shows the variation of the external radiation flow in telemetric units during the flight of Vega 1 balloon station. The increase in telemetric number indicates the decrease in the external radiation flow. When the balloon was drifting on the nightside, several cases of increased illumination were noted. Small variations in terms of one or two units are not taken into account at the present time, since they are at the level of the sensor and electronic noise. Some variations of the illumination on the nightside are correlated with large change in pressure and temperature. They are considerably greater than the instrumental errors across the whole temperature range (one or two telemetric units). This variation may be associated with the change in the attenuation factor of the thermal radiation "tail" at the planetary surface in the 1000 nm range, and (or) change in the diffusion coefficient for the same radiation by the cloud cover below.

The recording of solar light started at three Earth hours (on the basis of Doppler measurements of the zonal wind velocity), in other words 7°.5 , prior to the intersection of the terminator by Vega 1 balloon. The signal increases very rapidly when the balloon passes to the dayside. Since this telemetry was allocated only six less significant digits (of twelve) within the sensor signal, the curve 1,e shows rapid jumps, which is the digit transfer toward the more significant digit.

Although the telemetry data processing has not been finished as yet, and although in the future, some other interpretation of results may be possible, at this time one should draw conclusions

on the basis of the light flashes. Both balloons have not detected
a large number of light flashes at the time interval during which
the telemetry session was conducted. In total, these intervals
were about 7 h of observations, distributed more or less uniformly
across the flight trajectories. Only once it was possible to record
the signal by the flash sensor on the Vega 2 balloon, which may be
associated either with lightning in the atmosphere or with a
short term (less than 30 min) change in the average levels in the
light flow.

Both balloons had on-board the backscattering nephelometers
to study variation in the cloud cover density. The data generated
by nephelometer was obtained only from Vega 1 balloon, for all
telemetric sessions. The preliminary analysis indicates that:

1) within the general structure of the average cloud cover,
where the measurements were taken, it was not possible to detect
any regions of any strong manifestation, although it was possible
to measure the variation in density on a large time scale, along
the flight trajectory, which correlates with the decreased light
f lo w and temperature increase;

2) it was possible to measure fine distribution of the cloud
cover, which varies from the average by 20% order of magnitude;
on the whole these variations do not correlate with the ambient
temperature.

The absence of significant variation in the average cloud cover
density has already been noted earlier on the basis of the preceding
Venus probes (Knollenberg et al., 1980) and this correlates with the
intense convective and zonal moment and with the long life span of
the cloud cover particles.

The recorded decrease of the backscattering by the cloud cover
particles during long time intervals may be due to the descent of
the balloon into a less dense cloud cover, as one can see for ex-
ample by comparing the measurements of the clouds, as conducted
by Venus probes.

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THERMAL STRUCTURE OF THE VENUS ATMOSPHERE IN THE MIDDLE CLOUD LAYER

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Thermal structure measurements obtained by the Vega   /36
balloon show a generally adiabatic state, but suggest the
existence of separate air masses with slightly different
potential temperature and entropy. The temperatures as
measured by Vega 1 are higher by 6.5° K than the tem-
peratures measured by Vega 2, at the same pressure. The
measured data by Vega 2 landing module agrees with the
measured data as taken by Vega 2 balloon.

The flight of the two balloons of the Vega project was not
proceeding smoothly, at a uniform altitude (Sagdeev et al., 1986).
From time to time the balloons were moving vertically, several
kilometers, being affected by considerable vertical atmospheric
flows. In conjunction with this, the temperature and pressure
changes contain interesting information about the structure of Venus
atmosphere at the levels between 54 and 50 km. This region re-
presents a major part of the middle portion of the cloud cover
(Marov et al., 1980; Ragent and Blamont, 1980). As has been pointed
out earlier by Seiff et al. (1980), the temperature stratification
within this layer is somewhat unstable and presumably, there is
some convection.

The change of pressure and temperature in the case of each
Vega balloon and represented in P - T coordinates are all falling on
a straight line with the deviations from it of about ±0.5°K. There
are some points which are removed from the straight line by several
degrees, but they are primarily related to such time intervals for
which the ambiguity exists in the most significant digits of the
temperature measurements, recorded at the time interval of 10 min.

As one can see, a large amount of PT data obtained by each
balloon station shows a strong correlation between temperature and
pressure. However, the data from the two balloons, expressed in   /37
PT coordinates differ from each other for the same pressures by
approximately 6.5°K, and the temperatures of Vega 1 are higher.
In conjunction with the fact that the points of launching of the
balloons are approximately symmetric with respect to the equator

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(7°.3 south latitude and 6°.6 south latitude) the differences of
the two sets of PT data are surprising.

Figure 1 shows the measured temperature and pressures obtained
between 45 and 180° east longitude. They indicate that the dif-
ference between the PT sets for two balloon stations do not change
appreciably with the longitude. This may be related to the speci-
ficity of the balloon measurements, associated with the tendency of
the balloons to fly with the same air mass.

It is clear that the balloon stations during their flight were
within the air mass of different thermal background and that each
balloon remained in the same air mass for the greater part of its
flight time, after flying over one third of the Venus circumference.

The cause of temperature difference is of tremendous interest
for the dynamics of atmsophere. The atmospheric waves may generate
adiabatic compression, but the detected temperature difference may
be explained by it only if, and when, the wavelength is comparable
to the Venus circumference, because in the opposite case the tem-
perature difference would change with the longitude.

The observed temperature difference may also reflect the time-
related changeability in the atmosphere or the asymmetry in the
northern and southern hemispheres.
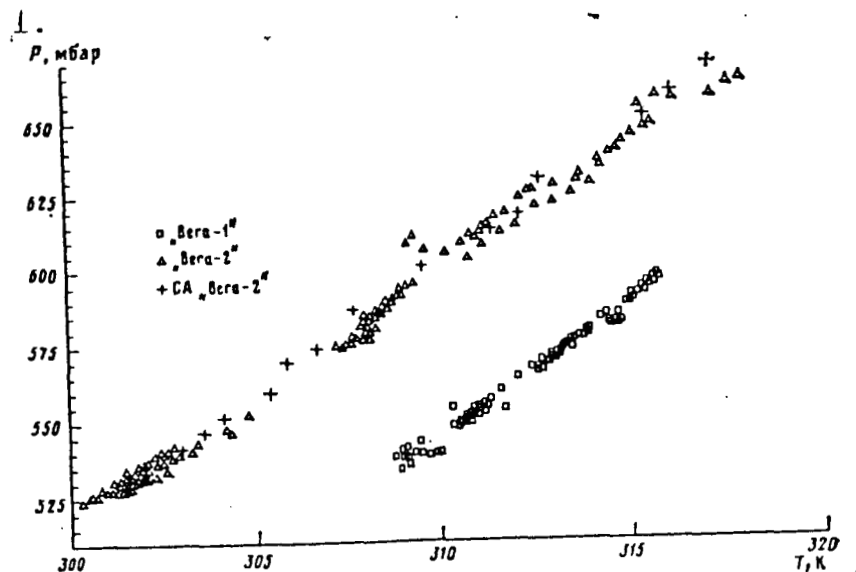
Figure 1. Results of the temperature and pressure measure-
ments on the Vega 1 and Vega 2 balloon stations.

Key: 1. P, mbar.
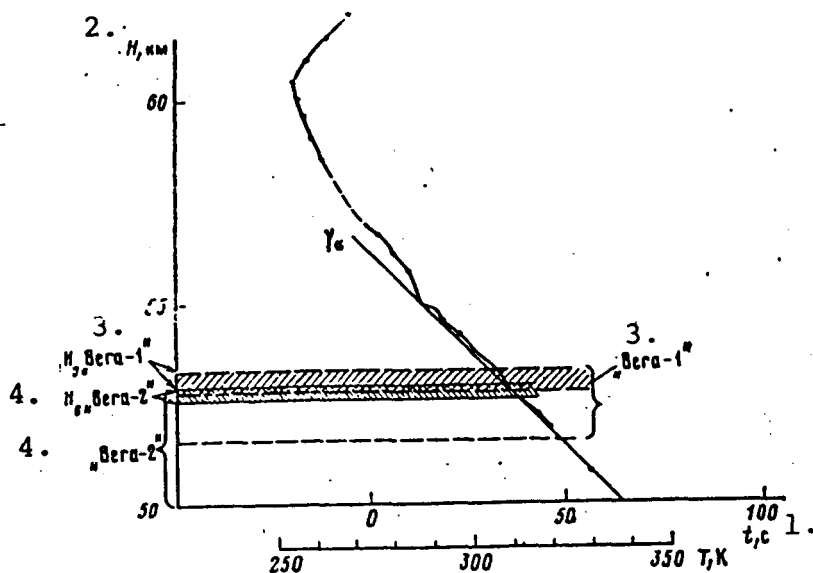
Figure 2. Region of the balloon's floating altitude and
the temperature curve as measured by Vega 2 landing module
(γ_a is the adiabat).

Key: 1. t, s; 2. H, km; 3. Vega 1; 4. Vega 2

To monitor the calibration of sensors, the PT measurements   /38
of the Vega 2 balloon were compared with the PT sensor measure-
ments of the Vega 2 landing module (in the area of the middle
cloud cover). As one can see in Figure 1, they fall on the same
straight line with the deviations of less than 0.5°K. In addition,
each balloon had the second temperature sensor
which was built-in into the nephelometer. The measured temperatures
by both sensors on Vega 1 and Vega 2 agree with the accuracy of
about 1°K, on the nightside of the planet, when there is no
nephelometer overheating by the solar radiation.

The temperature measurements of Vega 2 landing module at the
height above 50 km are shown in Figure 2. The same figure shows
the range of floating heights of the balloon. The height was cal-
culated on the basis of PT measurements of the Vega 2 landing module.
Below 55 km, the PT relationship as measured by the landing module
is close to adiabatic.

The temperatures, as measured by a large Pioneer-Venus
probe (Seiff et al., 1980) are lying between the temperatures of
the two balloon stations for the same pressure values. The values
of dT/dP derivative, which were determined on the basis of the
balloon data and on the basis of the large Pioneer-Venus probe
which has descended through the atmosphere at 4°.4 north latitude,
are similar. Because in the presence of hydrostatic equilibrium

$$\frac{dT}{dz} = \rho g \frac{dT}{dP},$$ the vertical temperature gradients are also similar.

Although the mean vertical temperature gradient may be determined from the data set for each balloon, it is better to compute it on the basis of the data from separate measuring sessions (Figure 3).

For example, Figure 3, a, shows the data from the measuring session V39 (Vega 2). This session coincided with the period of descending flow of w_d=2.5±0.5 m/s velocity, as a result of which the balloon dropped 0.57 km. The measured temperatures change primarily linearly with the pressure. The figure shows also the adiabat with the entropy S=R·26.45 (R is the gas constant). One can see from this figure that the atmosphere is close to adiabatic (during this session, the deflection of the points from the adiabat which, likely, is of regular nature, shows a somewhat stable stratification - of about 0.3°K/km). The adiabat in Figure 3, a, is used as a reference adiabat for the following curves.

Figure 3. Thermal structure of the cloud cover as measured by the balloon stations at short time intervals (during different reading sessions). The straight lines are different adiabats (see the text).
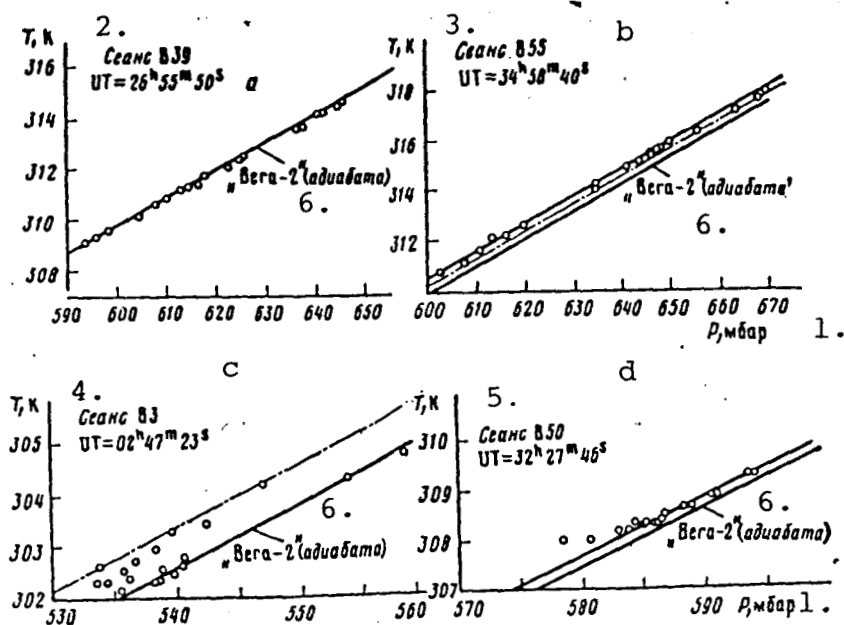
Key: 1. P,mbar; 2. Session V39; 3. Session V55; 4. Session V3; 5. Session V50; 6. Vega 2 (adiabat)

Figure 3, b, shows in an analogous fashion the data of V55 reading session, obtained immediately after crossing the terminator. It also falls on the adiabat, but is displaced with respect to the reference adiabat by $0.6^{\circ}K$. In reality, the data of this reading session forms two adiabats, separated by $0.24^{\circ}K$. The measured points moved from one adiabat to the other, which cannot be explained by the improper decoding of telemetric data (the ambiguities in the most significant digits). The measurements which we have here refer probably to a new air mass which participates in the descending movement during this reading session, with the vertical speed of $w_d=$ $=2-4$ m/s. The interpretation of the adiabat difference may be as follows. As the atmospheric stream flows around the balloon from above, downward, the sensor may be either in a new atmospheric environment or in the old one which is involved in the descending movement or in the mixture of the new and old atmospheric masses. Therefore, the measured temperature may be within the temperature range between these two masses. During this reading session, the descending flow existed for more than 30 min, and the atmospheric mass could have descended from the altitude of several kilometers above the balloon.

The analogous comparison of PT measurements for two other reading sessions is shown in Figure 3, c and d, when the Vega 2 balloon has registered the highest vertical speed. For the greater part of the reading session V3, the balloon flew almost without any change in altitude (at least not more than 100 m; the pressure in this case changed from 534 to 542 mbar), the vertical velocity of the atmosphere was between +0.5 to -0.8 m/s. Nevertheless, the measured temperatures have been distributed between the two adiabats, separated by $0.6^{\circ}K$ and were alternating between them four times during a 20-minute time period. For the vertical velocity of the atmosphere $w_a \sim 0.5$ m/s, this corresponds to the vertical scale of

different atmospheric masses ~150 m.

During the whole reading session V50, with the exception of the last several points ($308.0^{\circ}K$), the points fall between the two adiabats, separated from each other by $0.2^{\circ}K$. In this case, the vertical velocity of the atmosphere was -0.5 ± 0.5 m/s.

In conclusion, let us formulate the basic results of the preliminary analysis of the balloon measurements, in terms of the thermal structure of the middle part of the cloud cover of Venus: 1) in the course of vertical motions of both balloons, the temperature is strongly correlated with the pressure; 2) the balloons were placed into the atmospheric masses which differed in terms of temperature by $6.5^{\circ}K$ (at the same pressure) and the difference was retained within the longitude range between 180 and 70°; 3) within the middle part of the cloud cover, the atmosphere is close to adiabatic which is substantiated by the data of earlier experiments; 4) the observed small deviations from the same adiabat presupposes the existence of separate small atmospheric masses.

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VEGA BALLOON EXPERIMENT: MEAN ZONAL WIND VELOCITY IN THE ATMOSPHERE OF VENUS FROM DOPPLER MEASUREMENTS OF THE BALLOONS

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Doppler measurements of Vega balloons provided the estimates of mean zonal wind velocity in the atmosphere of Venus at (53-54) km altitude of (69±1) m/s for Vega 1 and (66±1) m/s for Vega 2; the wind has a westward direction. Within the wind velocity field, the manifested perturbation is likely connected with the solar perturbation.

The possibility of the existence of strong winds in the upper cloud cover of Venus atmosphere has been pointed out for the first time (Boyer, Charmichel, 1961) on the basis of the UV data, obtained on the Earth. The Doppler measurements from Venera station (Kerzhanovich et al., 1969; Kerzhanovich and Marov, 1983), and at a later time, the measurements from the Pioneer-Venus (Pioner-Venera) probes (Counselman et al., 1980) have shown that the Venus atmosphere, beginning at the height of 65 km and up to ~10 km, displays a strong zonal movement, in the direction of the planetary rotation. This phenomenon has not been adequately explained so far, and has not been investigated phenomenologically.

The balloon probing made it possible, in principle, to generate some new data in terms of the 24-hour longitudinal change of the wind velocity.

The wind velocity in the atmosphere is determined on the basis of the balloon trajectory changes, as the former floats with the wind. The complete tridimensional picture of motion will become clear after conductance of the radio interferometry signal data processing, with the signals obtained by means of the global interferometry network, consisting of 20 radiotelescopes (Preston et al., 1985, 1986). For the preliminary estimation of the mean zonal circulation and also that of a small-scale turbulence, we have utilized the data of the signal frequency Doppler measurements, obtained by the balloon probes. The method of measurements and interpretation are similar to those which were used during the interplanetary spacecraft flight Venera 4-8 (Kerzhanovich, 1972).

The signal frequency obtained from the balloon was generated by the thermally insulated, quartz master oscillator (MO). The deviation of the assigned frequency f_a from the nominal f_0 is equal to the sum of the Doppler shift f_D (proportional to the projected velocity of the balloon with respect to the point of reception at the sighting line) and the current deviation of MO frequency from the nominal $\Delta f_1(t)$. In determining the velocity while processing the measurements we took into account the ground testing of MO frequency drift, $\Delta \tilde{f}_1(t)$. Therefore, the major quantity which is being observed is

$$f_a' = f_a - f_0 \Delta \tilde{f}_1(t) = f_D + \Delta f_0 + \Delta f_1'(t),$$

where Δf_0 is a constant (during the flight) MO frequency deviation from the nominal, $\Delta f_1'(t)$ is the difference between actual and prognosticated frequency drift during the flight. The Δf_0 quantity is introduced into the set of the refined parameters in the course of the data processing and the $\Delta f_1'(t)$ quantity defines the major error of measurements. On the basis of ground tests $|\Delta f_1'| < 3\text{-}4$ Hz, or   /43
0.5-0.8 m/s, if recalculated in terms of speed.

The signal isolation and evaluation of parameters was accomplished by computer, utilizing the methods of digital signal processing. The accuracy of measured frequency f_a was about 0.1 Hz (0.02 m/s), if recalculated in terms of speed). For the evaluation of the mean wind velocity, the data from tracking stations in Evpatoriya, Ussuriysk, Madrid, Goldstone and Canberra was used. The measurements obtained at different stations agree within the overlapping ranges with the accuracy better than 1 Hz. For each communication session, we have utilized one most reliable reading.

In order to obtain the Doppler shift, related only to the balloon movements with respect to Venus center, one subtracts from f_a' quantities the calculated Doppler shift "Venus center-reception point." The results of measurements for both balloons are shown in Figure 1. One can see that on the whole, the character of the Doppler shift for both balloons is analogous and the major difference is in Δf_0 quantity.

The diagram of the drift of the balloons is shown in Figure 3, of the article by Sagdeev et al. (1985). The geometry was such that the central (underground) meridian was in the vicinity of the terminator. The observed character of the Doppler shift change is primarily associated with the change in the balloon velocity, as

projected toward the Earth: in the beginning of the flight, near the limb, the balloon velocity is aimed at the Earth and the Doppler shift is at a maximum, near the central meridian - it approaches zero, and then becomes negative as the balloon begins to approach the left edge of the limb.

Both balloons were activated near Venus equator so that the Doppler measurements were sensitive predominantly with respect to the zonal component of the wind velocity. By taking this into account, while estimating the wind velocity, we have utilized the simple model of a purely zonal motion with a constant speed u_0. In such case, the computed frequency f_a' is equal to

$$f' = \frac{1}{\lambda}(u_0 + u_r)\cos\varphi_0 \cos\varphi_e \sin\left(\lambda_0 - \frac{u_0}{a}(t - t_0) - \lambda_e(t)\right),$$

where a is the planetocentric distance of the probe (6106 km), λ_0, ϕ_0 are the planetocentric longitude and latitude of the points where the balloons were activated, $u_r \approx 3$ m/s is the linear displacement velocity of the underground points, λ_b, ϕ_b are the longitude and latitude of the underground point, $\lambda \approx 18$ cm is the wavelength. The u_0 and Δf_0 quantities were determined by the method of the least squares. In evaluating Δf_0, the measurements near the central meridian were also used (where the Doppler shift is at a minimum in terms of its absolute magnitude). The difference in these evaluations does not exceed 2 Hz (0.4 m/s in terms of speed).

Figure 2 shows the Doppler remainders (the difference between measured and calculated Dopper velocities) for both balloons, for u_0=69.3 m/s, Δf_0=-16.7 Hz in the case of Vega 1 and u_0=66.4 m/s, Δf_0=-340 Hz in the case of Vega 2. The Dopper remainders are quite sensitive to wind velocity so that the error in u_0 estimation does not exceed 1 m/s. As one can see, the difference in the wind /44 velocity on Vega 1 and Vega 2 is a real one. One can see first of all that the constant wind indeed correlates well with the measured data: the magnitude of the Doppler remainders, on the average, does not exceed 2-3 m/s, which, if one is to take into account the geometric factor, corresponds to the possible variation of the wind velocity of not more than 4-6 m/s (within the zone where the balloon longitude differs from the central meridian longitude >20°).

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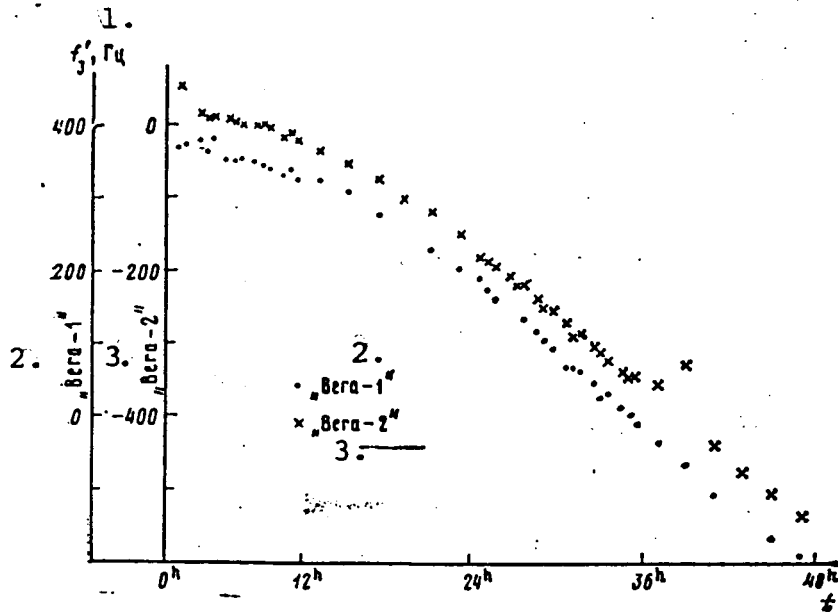
Figure 1. Doppler frequency shift of the balloon signal.
Time UT=0. corresponding to 0 h, June 11, 1985 for Vega 1
and 0 h, June 15, for Vega 2. Along the y axis - to the
left is Vega 1 scale and to the right is Vega 2 scale.

Key: 1. Hz; 2. Vega 1; 3. Vega 2
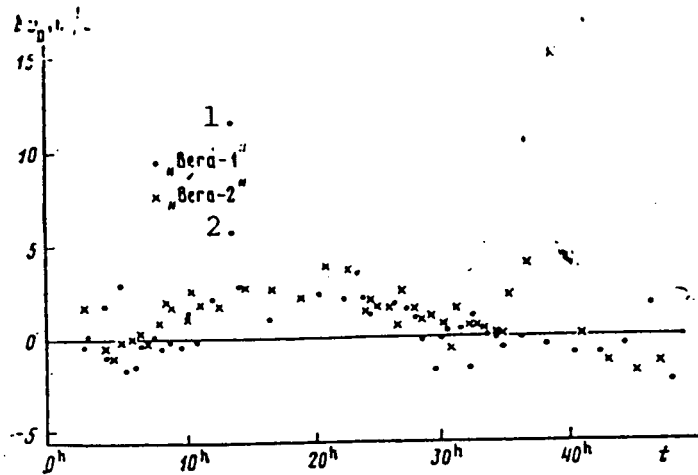
Figure 2. Dopper remainders for the model of purely zonal
constant wind, the velocity of 69.3 m/s in the case of Vega 1
and 66.4 m/s in the case of Vega 2.

Key: 1. Vega 1; 2. Vega 2

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Event	UT	Longitude	Lati-tude	Longi-tude of ter-minator	Traversed distance, km
		Vega 1			
Injection or acti-vation	02ʰ06ᵐ10ˢ	176°.9	8°.1	−84°.6	0
Passage through the terminator	36 20	97.5	8.1	0	8 500
Passage through the central meridian	36 40	98.2	8.1	2	8 700
Last communication session	48 38	68.8	8.1	30.3	11 600
		Vega 2			
Injection or acti-vation	02 06 04	179.8	−7.5	−75.4	0
Passage through the terminator	33 10	111.0	−7.5	−2	7 400
Passage through the central meridian	33 50	109.4	−7.5	0	7 600
Last communication session	48 38 01	76.3	−7.5	35.0	11 100

The determined wind velocities of 69±1 m/s in the case of Vega 1 and 66±1 m/s in the case of Vega 2 make it possible to evaluate in the first approximation the trajectory of the balloons. The basic data of trajectories is shown in the table. Both balloons began their drift near midnight and finished the active transmission of data at about 8 o'clock in the morning, solar time, on Venus (the zenith solar angle 30° and 35°).

The determined mean wind velocities of 5-10 m/s exceed the values for this altitude obtained during the preceding experiments, which indicates a real, time-related changeability of circulation. One can see from Figure 2 that the data obtained at both balloons shows similar sinusoidal changes of the Doppler remainders with the amplitude of 2 m/s and the maximum in the vicinity of 20 h UT, or 3 h 30 min, local solar time on Venus. In principle, this may be associated with the manifestations related to the solar perturbations (for example, the solar tides).

The only area where the Doppler remainder becomes large (~ 15 m/s) is the region of the "great event" on Vega 2, which has been noted on the basis of the meteorological sensor readings (see

Blamont et al., 1986). If we are to use our estimate of the
trajectory, the Vega 2 balloon was at that time near a peak about
5 km high, over the Aphrodite Terra. To some extent the observed
change in frequency may be associated with the MO temperature drift
(the balloon had descended here 2 km, and the atmospheric tempera-
ture had increased by 20°C), but it is clear that the greatest part
of the frequency change is associated with the change in the nature
of the balloon motion.

A rough evaluation indicates that the observed change in the
Doppler remainder may correspond to the increase of meridional
velocity by several dozen meters per second, but a final conclusion
may be drawn only on the basis of the radio interferometry data
processing.

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VEGA BALLOON EXPERIMENT: SMALL-SCALE TURBULENCE IN THE MIDDLE CLOUD LAYER OF VENUS

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From the measurements of variations of the Doppler /46
velocity on Vega balloons, a strong turbulence was de-
tected in the cloud cover, both on the dayside and the
nightside of Venus. The amplitude of wind velocity
variations as a function of time scale of 30-100 seconds
was up to 2 m/s.

1. Introduction. There were several proofs of the small-
scale movement of Venus atmosphere: the speed variation of the
landing modules Venera, associated with the turbulence (Kerzhanovich
et al., 1970; Kerzhanovich and Marov, 1983), the amplitude fluc-
tuations of the radio signals caused by the temperature variations
(Gurvich, 1969; Woo and Armstrong, 1980; Timofeeva et al., 1980)
and small convective turbulence cells, showning up on the UV images
(Murray et al., 1974).

The data from Venera had shown that the noticeable turbulence
frequently is not being observed above 40-45 km, and that the velo-
city variations may reach 1-3 m/s, that the turbulence distribution
is homogeneous and that the scale of movements changes from 300 to
1000-1200 m. The last interpretation of the radio signal ampli-
tude fluctuations resulted in the two-layered turbulence distri-
bution at the height of about 60 and 49 km, with the external scale
of about 5000 m for the upper layer.

The Doppler data from the Vega balloons produced some new information
on turbulence in the middle cloud cover, which is one of the most
important regions from the point of view of the dynamics of the
atmosphere. In planning this experiment, it was expected that be-
cause of the Lagrange character of the balloon motion (the move- /47
ment together with the gaseous mass) one would observe only small
velocity variations.

2. Measurements. In the case of this analysis, we have
utilized the routine, automated Doppler measurements, with the
discreteness of 0.5 s, obtained by the Institute of Radio Engineering
and Electronics of the Academy of Sciences of the USSR, by digital

processing of the signals, obtained from Evpatoriya station. The data set for both balloons consists of 62 intervals, with the length of 332 s, each. The error of each measurement is less than 5 cm/s. The accuracy is limited by the signal-to-noise ratio and by the short term stability of the on-board master oscillator. The data for all 69 operational sessions for each balloon will be generated in the future.

The Doppler shift variation is directly related to the actual movements of the balloon, as projected along the sighting line. Therefore, when the balloons were near the limb, the variations in Doppler velocity were defined primarily by the variations in horizontal speed, the variation near the central meridian - by the variations of vertical speed and within the intermediate regions - by the combination of both.

Because the temperature gradient at the floating height is close to the adiabatic one, the small-scale turbulence, as it appears, is isotropic and one could expect that the variations in vertical and horizontal speeds are approximately the same. The vertical motion of the balloons on the intermediate time scale, in other words the variations which are sufficiently large as compared to the minimal balloon time constant (10 s) and sufficiently small, when compared to the maximum time constant (300 s) trace out quite well the movements of the atmosphere. The correction factor for the scale of 30-100 s is ~1.5 for the vertical motions and ~1.2 for the horizontal ones (the accounting for the dynamics of the balloon motions will be carried out in the future by digital modelling).

One must make here one important comment. The external balloon surface is a sufficiently smooth sphere and in the presence of small relative speeds of gas (0.5-2 m/s) the Reynolds numbers turn out to be close to the critical ones. It is known from the experiments in the terrestrial atmosphere (Scoggins, 1965) that in such case the movement of a spherical probe itself may be of oscillatory character. The period of oscillations may be about 5 s and more. It is not excluded therefore that the observed variations in the Doppler velocity may be partially related to such instability of the balloon motion itself. As it appears to us however, the character of the observed variations, their periods and amplitudes, indicate the fact that the balloon motion itself is not the major factor and that the atmospheric turbulence is the major one. Of course, for a strict evaluation, a more thorough analysis is required. After saying that much, we shall associate in this study the variations of speeds with the periods which are greater than 30 s, as the manifestation of atmospheric turbulence.

3. Results. It turned out that the dynamic activity in Venus atmosphere is considerably more intense and more changeable than it was suspected before (the same refers to all experiments on the balloon). The examples of velocity variations in the case of both balloons are shown in Figures 1 and 2. In these figures, the ex- /48 ample of each balloon's motion in the calm and turbulent atmospheres are shown. In the case of Vega 1, the selected trajectory segments refer to the beginning of the flight and correspond to the variations of horizontal speed, and in the case of Vega 2 - toward the end of the active flight and correspond to the variations of vertical speed. Let us note the comparatively short time (1-3 h) as one proceeds from the calm to turbulent segments.

Within the intervals of Doppler measurements (each 330 s), one can observe the variations on two different time scales: 7-10 and 6-130 s. As it appears, the shorter one is related to the pendulum-like oscillations of the gondola (period of 7-8 s). The pendulum oscillations are of small amplitude (less than 1°, which corresponds to the amplitudes in the variation of Doppler shift of 1 Hz or 20 cm/s, in terms of speed). These could be observed quite clearly at the beginning of the Vega 1 flight, where a considerable turbulence was manifested and where one still could be faced with the perturbations, associated with the unfolding of the balloon and its filling. The Doppler shift here is quite sensitive to the horizontal speed.

The other type of natural oscillations of the balloon are the /49 vertical motions which are associated with the retention of the equilibrated flight altitude, because of the floating nature of the flight and these display a significantly greater period - 300-400 s. At the same time, their amplitude (recalculated in terms of the speed) is ~20 cm/s, and has no significant influence on the interpretation of measurements.

Of the greatest importance are the variations on the time scale of 6-130 s, since they reflect to a large degree the real turbulence of the atmospheric motions. Figure 3 shows the maximum amplitudes of the Doppler velocity variations for both balloons during the flight. The real variations of the wind velocities exceed these variations approximately by a factor of 1.5.

One can see from Figure 3 and also from Figures 1 and 2 that the turbulence displays strong and irregular changes. Let us emphasize that the above-mentioned variations reflect the actual changeability of the turbulence and are not associated with the errors in measurements. The Doppler data correlates quite well with the mean vertical motions of the balloons, determined on the basis of the temperature and pressure changes.
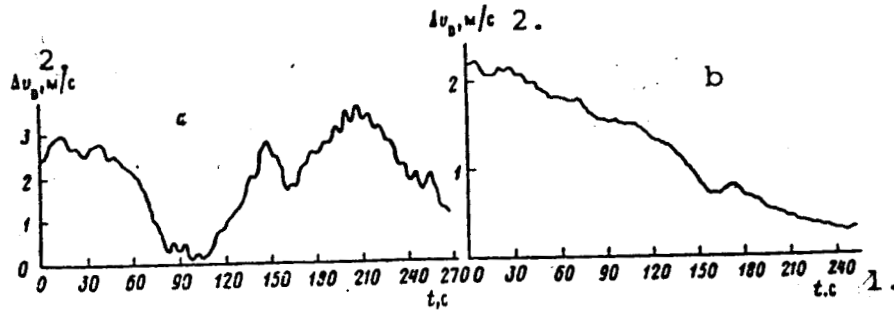
Figure 1. Examples of the Vega 1 balloon speed variations:
a - operational session No. 15, beginning at 09 h 24 min 15 s UT,
b - session No. 17, beginning at 10 h 24 min 30 s UT.

Key: 1. seconds; 2. m/s
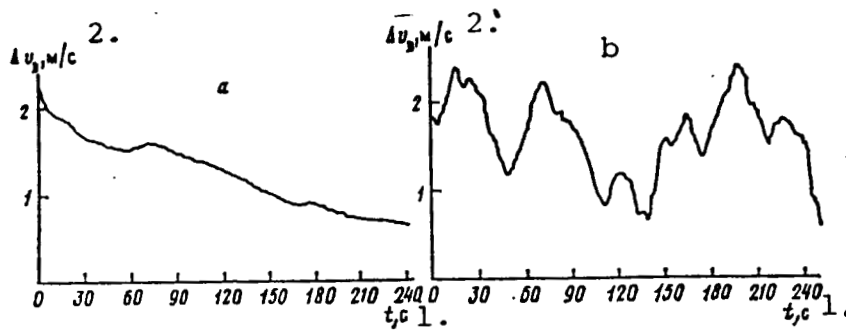
Figure 2. Examples of the Vega 2 balloon speed variations:
a - operational session No. 50, beginning at 32 h 02 min 30 s UT,
b - session No. 56, beginning at 36 h 03 min 35 s UT.

Key: 1. seconds; 2. m/s

The amplitude of speed variation changes from 0.05 to 1 m/s in the case of Vega 2 and even up to 2 m/s in the case of Vega 1. Transition from calm to turbulent trajectory segments may occur rapidly and irregularly (see Figure 1 a and b, in which the intervals between the data reading is 1 h) for both Vega 1 and Vega 2. Nonetheless, one can see some common features. During the first 11 hours of the flight, the variations in horizontal speed in the case of Vega 1 were significantly greater than in the case of Vega 2, for which this segment was practically quite calm. On the other hand, between the 24th and 37th hour (UT) when the balloons were close to the central meridian (and the Doppler data is sensitive primarily to the variations of vertical speed), the variations in speed in the case of Vega 2 were greater by a factor of 2-3 than the case of Vega 1.

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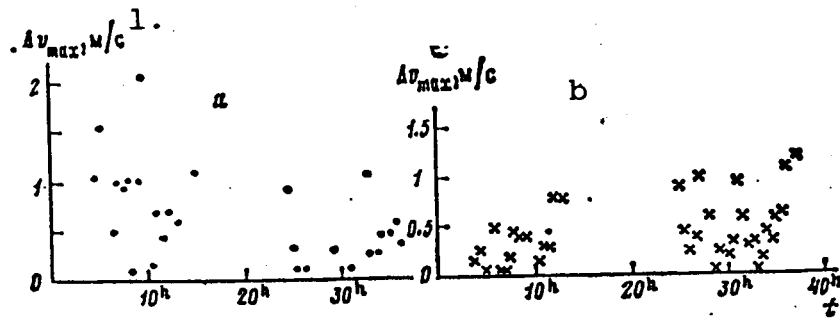
Figure 3. Maximum amplitude of the balloons speed variation, related to the effects of turbulence: a - Vega 1, b - Vega 2

Key: 1. m/s

4. Discussion. If one is to accept as a threshold of the turbulence detection the amplitude variation of 0.2 m/s, one can see from Figure 3 that in all likelihood, the presence of turbulence is more than 50% during 4 days and nights - a figure /50 which is significantly greater than in the case of the terrestrial atmosphere. Although the similar values of probability of repeat turbulence at this altitude were obtained on the basis of the Doppler data during the preceding interplanetary Venera flights, it was quite unexpected that such considerable turbulence will be detected also on the nightside in the case of the balloon experiment, when the latter may be viewed as the Lagrange particles, moving together with the gas.

The differences between Vega 1 and Vega 2 data indicates that there are some similar regions within the atmosphere which have different properties. It is not excluded that the significant turbulence detected by Vega 1 during the first quarter of the flight is associated with somewhat warmer atmospheric mass, through which the balloon was moving (Linkin et al., 1986). It is also possible that the large vertical movements of Vega 2 during the second day of the flight are in some way associated with the passage above the mountainous region of Aphrodite Terra. The most likely cause of turbulence at the floating height is the thermal convection (the temperature gradient here is close to the adiabatic one) (Linkin et al., 1986)).

The variation of speed on the scale of 30-130 s is probably associated with the evolution of small convective turbulence cells, while the alternation of the calm and turbulent zones (30-90 min) probably is associated with the presence of large turbulence cells. It is difficult to estimate at this time the spatial scale of the convective movements. The speed of the balloon movement, driven by the atmospheric wind, was about 70 m/s, so that in the course of 60 s (the mean time scale of turbulence) they were traversing about 40 km, and during the time period of 330 s (the time of

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the communication session) - about 20 km. During the time between two communication sessions, they have traversed a distance of 130-250 km. One might surmise that the convective turbulent cells are moving along somewhat more slowly than the mean flow and that their speed is lower by several meters per second than the mean speed of the atmospheric wind. In such case, the speed variations on the time scale of 60 s would correspond to the turbulence cell of several hundred meters in size, and the variations on the scale of 30-60 min will correspond to large turbulence cells, the size of which is on the order of several dozen kilometers. It is interesting that the turbulence cells of such size have been observed on the upper boundaries of the cloud cover, on the basis of UV images, obtained by Mariner 10 (Belton et al., 1976). And in addition, the lifetime of such cells was several dozen minutes which is close to the data obtained by us.

Both balloons flew at the height of about 54 km - exactly between the alleged turbulence layers (49 and 60 km), which, according to Woo and Armstrong (1980) are causing the fluctuations of the radio signal amplitudes in the experiments of radio transmittance. The balloon probing data substantiates the data from Venera as to the presence of strong turbulence in the middle cloud cover: the distribution of turbulence is close to the homogeneous one. The cause of the seeming difference, as has been pointed out earlier (Kerzhanovich and Marov, 1983) may be the fact that the amplitudes of radio signal fluctuations are affected by the temperature pulsation which may be inversely related to the wind velocity fluctuations, affecting the movement of the balloons through the atmsophere.

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VEGA BALLOON EXPERIMENT: PRELIMINARY ANALYSIS OF MEASUREMENTS IN APPLICATION TO THE DYNAMICS OF THE ATMOSPHERE OF VENUS

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The typical vertical wind velocities measured by the /52
Vega balloons are (1-2)m/s and probably may be explained
by the thermal convection. The temperature difference
between Vega 1 and Vega 2 data may be due to the per-
turbations of synoptic or planetary type. The Doppler
data indicates high wind velocities as compared to the
previous experiments and the possible presence of per-
turbations associated with solar activity. It appears
that the Vega 2 balloon movement was affected by the
surface topography.

The purpose of the balloon experiment within the Vega project
was to study the parameters of Venus atmosphere at the floating
height, including the investigation of horizontal and vertical
winds, the structure and properties of the cloud cover, emphasizing
and paying great attention to the dynamic processes. We shall dis-
cuss in this article the preliminary interpretation of the measured
results. The data continues to be processed, so that in the future
some changes and supplementary information may be added. In addi-
tion, a part of these results (for example, the radio interferometry
trajectory measurements) has not been obtained as yet.

The vertical transfer of a quantity of motion and heat is one
of the major factors which define the parameters of the general
atmospheric circulation, and therefore the measurement of the
vertical wind on the balloons is of great interest. One of the
most interesting features derived from this data is the great
vertical wind velocity w, which has been observed on the dayside
and on the nightside of the planet. The typical w quantities
exceed 0.5 m/s, and the maximum figures reach 4-5 m/s. Because of
some ambiguities in the calculations of vertical velocity (Kremnev
et al., 1986) the maximum amplitudes may be lower than those indicated
by Sagdeev et al. (1986). The mean values of the amplitudes however
do not change.

One might expect that there are substantial vertical winds in /53
the areas with low static stability (Seiff et al., 1980; Linkin
et al., 1986a), in the middle cloud cover (Marov et al., 1980;

Knollenberg et al., 1980) which affect appreciably the physics of
the clouds and the atmospheric circulation. A significant vertical
mixing may affect such microphysical properties as the distribution
of the cloud particles in terms of size and charge. The intense
exchange, in the quantities of motion and heat, in the area with
low static stability probably results in the noticeable local
effects in the wind fields. For example, it is known that the
vertical shift of the zonal wind velocity, measured by Venera probe
and the Pioneer-Venus probe (Kerzhanovich and Marov, 1983; Counselman
et al., 1980) are close to zero here, which in all probability is
the result of intense atmospheric mixing in this area. The con-
vective motions may generate the atmospheric waves propagating
through the atmosphere with relative high static stability. Such
waves may affect the distribution in the quantities of motion at
the levels which are far away from the convection area.

The mean value of w, in a general case, correlates well with
the estimates of convective movements, using the theory of the
atmospheric pathway mixing (Cox and Giuli, 1968)

$$|w| \sim \left(\frac{Fgl}{4\rho c_p T}\right)^{1/4} \approx 2 \text{ m/s},$$

where F is the convective heat flow which is assumed to be equal to
the mean flow of solar radiation at the height of 64 km (40 W/m^2),
g is the force of gravity, ρ is the density at the height of the
floating balloon, c_p is the heat capacity at constant pressure and

T is the temperature. The F quantity was selected on the basis of
the following considerations. The energy which the convective mass
motions will move to the top of the convective zone is the IR
radiation of the lower atmosphere. We have assumed that the whole
ascending flow is absorbed (although the $|w|$ value, according to
the formula as presented, is only slightly sensitive to F quantity).
The flow depends on the temperature which in Venus atmosphere changes
only slightly, so that this flow will be equal to the mean solar
radiation. The length and pathway of mixing l was assumed to be
equal to 5 km (which is close to the height scale). If we are to
reduce it to 1 km, this will change the estimated $|w|$ by a factor
of less than 2. However, the large vertical winds with the ampli-
tudes of 3-4 m/s, recorded by both balloon stations, particularly
in the case of the nightside, are probably due to different causes.

On the basis of the theory of mixing, one can also estimate
the magnitude of temperature fluctuations which correspond to the
vertical winds of 2 m/s velocity:

$$\Delta T = \delta T \frac{|w|^2}{gl} \approx 7.5 \cdot 10^{-2} \text{ K}.$$

In the course of specific telemetry sessions, the data of
which is being analyzed at this time (each session embraces 30
min interval of measurements), the temperature fluctuations are
precisely of such order (0.1°K).   In the other cases however,
the ΔT quantity reaches 0.5-0.7°K.   The final conclusions can be
drawn only after more complete analysis.

On the basis of Doppler measurements, it was possible to
detect the small-scale movements of the balloons.   The speed
variation is ~1 m/s at the time scale of ≳60 s (Kerzhanovich et al.,
1986).   It is difficult at this time to state unambiguously whether
they are related completely to the turbulence or are caused by the
aeronomics of the balloon itself, with the continuous atmospheric
wind flowing around it.   However, the results of the preceding
Venera probes indicate that the turbulent wind velocity variations
at this height have been observed with a sufficient degree of
probability and may reach 2-3 m/s (Kerzhanovich and Marov, 1983).

The other interesting feature of the vertical winds as measured
from the balloons is their predominant descending nature.   This
probably reflects not the properties of the atmosphere, but rather
the specifics of the balloon probing.   One can see from the data,
as obtained by the landing modules, that the balloons were floating
primarily in the upper region of the convective zone.   A rapid
growth of static stability acts as "upper boundary" of the con-
vective zone, since the vertical velocities decrease with the in-
crease of static atmospheric stability.   In the upper segment of
the convective zone, the regions of descending movements coincide
with the areas of converging horizontal winds and in the areas of
the ascending movements - with the regions of divergence.   In such
conditions, the balloon tends to remain predominantly in the areas
of descending vertical movements, something which is reflected in
the measured data.

Further, the Vega 1 and Vega 2 balloon stations have discovered
the difference in potential temperatures of ~6.5°K, which has been
traced out during practically the whole length of flight.   This
means that the greatest length of time of the balloons' flight and
their movements took place together with the atmospheric gaseous
masses which are of different origin.   The importance and the
connection of this fact with the dynamics of the atmosphere may
lie either in the fact that between the northern and southern
hemispheres there is a significant asymmetry, which begins to be
noticeable already at the latitude difference of ~14°, or that
there are time and/or longitudinal changes which exist within the
structure of the atmosphere.

Both of these mechanisms may contribute to the observable
temperature differences.   As has been indicated earlier, the dif-
ference of potential temperatures of 6.5°K exceed significantly

the difference which may be related to the turbulent mixing within
the convective layer. Therefore, it is more likely that here the
large scale processes begin to manifest themselves. It is un-
likely that there is a mean asymmetry between the hemispheres which
may play a great role in maintaining a noticeable difference in
the potential temperatures. As it appears, the noticeable dif-
ference is the result of perturbations on synoptic and global scales.
The vertical scale of these perturbations must have the magnitude
on the order of the convective layer thickness or more, so that
they would not significantly decrease within this layer. In addi-   /55
tion, in order that the difference of potential temperatures be-
tween the balloons would be retained the perturbations must propa-
gate within the zonal direction, approximately with the velocity
of the central flow.

The probability of large scale perturbations may be seen from
the Doppler measurements. Figure 2, shown in the study by Andreev
et al. (1986), which depicts the deviation of Doppler velocity
from calculated values, corresponding to the constant wind, shows
that this change occurs relatively smoothly, starting at the Venus
midnight and toward dawn, and the magnitude and sign is similar in
the case of both balloons. We cannot say at this time whether this
is associated only with the zonal or with the meridional winds, or
with both. An unambiguous answer will be possible only after study-
ing the interferometry trajectory data for the balloons, which are
to be processed. On the basis of the shapes of the deviations, ob-
tained in Doppler measurements, it seems that the balloons have
registered the perturbation associated either with the Sun or with
the planet. The most probable stationary perturbation on a planetary
scale is the solar thermal tide. The 12-hour thermal tides in the
upper troposphere (65 km) were detected on the basis of IR radio-
meter measurements by Pioneer-Venus probe (Scofield and Taylor, 1983).

The manifestation of time-related perturbations is associated
with the noticeable higher mean zonal velocity (higher by 6-10 m/s),
measured by the balloons, when compared to the previous experiments.

An intersting feature of the obtained data is the different
nature of change in vertical winds as a function of time, measured
by both balloons. During the whole length of the flight, the Vega 1
balloon stations have encountered the periods of intense descending
flows. The most intense flow occurred at the beginning of the
flight, when the velocity of the descending flow reached 3 m/s.
For the first 20 h of flight, the Vega 2 balloon was moving in
calm conditions and the changes of the mean floating height were
less than 100 m. Then the nature of the vertical motions has
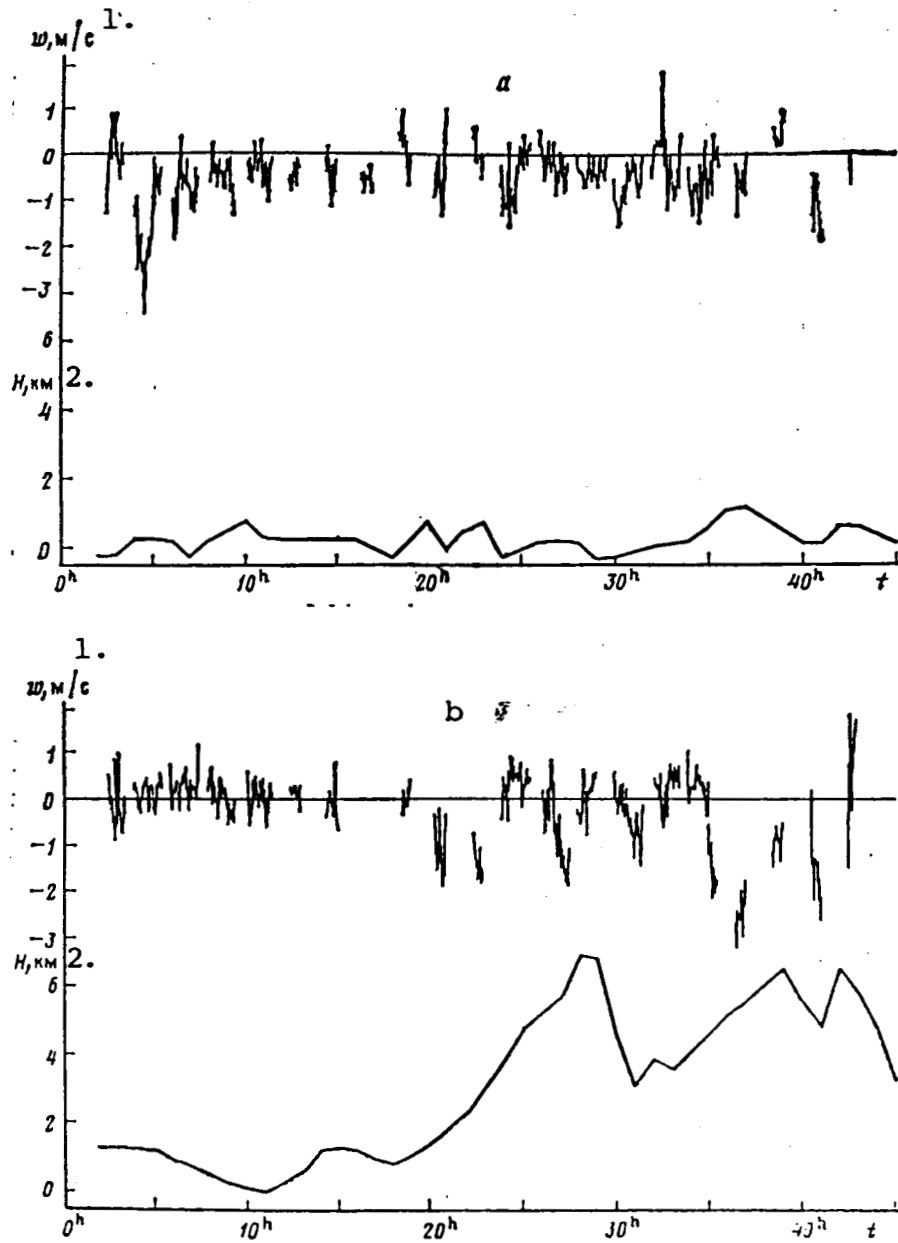changed and it began to resemble the flight pattern of Vega 1
balloon.

Figure: Vertical wind velocity based on Vega 1 data (a) and Vega 2 data (b) and the topography surface relief along the trajectory of the balloons.

Key: 1. m/s ;   2. km

The strong descending movements are clearly seen from the temperature and pressure measurements (Sagdeev et al., 1986) and also from the Doppler data (Kerzhanovich et al., 1986).

A very large variation of Doppler differences (corresponding to the change in the horizontal velocity of several dozen meters per second), of the altitude, temperature and pressure were observed on Vega 2 balloon between the 35th and 40th hours, UT. It should be noted that although the excess pressure within the balloon shell of Vega 2 has decreased to zero, while descending to the level of 700 mbar (this resulted in its enhanced reaction toward the vertical wind), the temperature and pressure variations, even before the interior pressure was lost, were at a maximum. As it appears, the character of change in Vega 2 data between the 35th and 40th hour, UT, and even before that, may reflect the effect of topography on the atmospheric movements. The figure shows an example of the topography relief along the trajectory of each balloon. The estimated balloon trajectory was made on the basis of Doppler measurements (Andreev et al., 1986) in the assumption /57 that the movement is purely zonal. The planetary surface height were obtained on the basis of altimeter data from Pioneer-Venus (Pioner-Venera) probe (Masursky et al., 1980). To be sure, this data must be approached cautiously, since first of all the estimated trajectories are at this time only of preliminary nature, and secondly, the actual topography relief may be considerably different from the data obtained by the altimeter (the altimeter was measuring the mean height values across the surface area of 3000-4000 km^2).

The following can be seen from this figure. First of all the exceedingly high variation of the measured parameters on Vega 2 definitely took place as the balloon flew over the mountainous region of Aphrodite Terra. Secondly, the variation in height of the mountains, over which Vega 2 balloon had flown, was significantly greater than in the case of the balloon trajectories of Vega 1. Thirdly, although the Vega 2 balloon has intersected the terminator at the same time as it flew above the Aphrodite Terra, it is unlikely that the terminator intersection by itself would have played a significant role because, as Vega 1 balloon was intersecting the terminator, it did not experience any particular vertical perturbations.

If the topography in the area of Aphrodite Terra does indeed affect the temperature field and wind velocity at the balloon floating heights, this may be the manifestation of two mechanisms. The first one, in our opinion the most unlikely one, is the existence of active volcanic activity. In such case, it is rather difficult, although not impossible, to explain why the eruption would cause the descending movement of the balloon. The second and more likely one, is the mountain-related downwind atmospheric

wave movements. Although there are no appropriate calculations which have been conducted so far, Shubert and Waltercheid (1984) have shown that in the case of some real profiles of static stability and wind velocity, some types of gravitational waves, caused by the surface, may reach the upper atmosphere of Venus. It can be seen from calculations that under certain circumstances, the wave amplitudes in the upper atmosphere may be significantly enhanced. To be sure, further studies are necessary in order to be quite certain as to the effect of topography at the height of the balloon flight.

Even the preliminary analyses of the results obtained by Vega 1 and Vega 2 balloon stations have shown their unique nature in terms of quality and quantity, as well as in terms of the general influence on further understanding of the dynamics related to Venus atmosphere.

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VLBI NETWORK AT 18 cm WAVELENGTH

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The main parameters are given of the Soviet 18 cm   /59
VLBI network including five elements with interferometric
baselines from 100 to 7000 km. Antennas are equipped with
hydrogen frequency standards, low-noise amplifiers and
2 MHz bandwidth recording systems. The network is destined
for astrophysical observations as well as for astronavigation
and geodesy purposes.

The superlong base interferometry is one of the important
trends in the development of present-day radio astronomy. Because
of successes in this area, it was possible to obtain the detailed
depictions of quasar nuclei and of radiogalactics, to study the
shells of stars and the areas of star formation and that of the
planetary systems. This method is extensively used in handling
the applied problems in astrometry, in astronavigation, in geo-
dynamics and in other areas. This is associated with extremely
high angular resolution of modern radio interferometers with in-
depenent signal recording. It improves the angular resolution of
the best optical telescopes by several orders of magnitude, reaching
several dozen microseconds of arc. At the present time, a number   /60
of radio interferometry networks have been developed and are success-
fully operating, including practically all large radiotelescopes
of the world and forming a unified, global instrument. This system
includes also the radiotelescopes RT-22 at the Crimea astrophysical
observatory of the Academy of Sciences of the USSR. For a number
of years already, the radio interferometer operates successfully
at the wave of 1.35 cm. The instrument consists of two 22-m and
one 70-m antenna (Matveenko et al., 1983). In order to facilitate
further development in our country of this type of reseach in
this area, a number of antennas were investigated, including a
recently activated second 70-m antenna, which was equipped for
radio interferometry work.

Selection of the wavelength. At the first stage of the radio interferometry network development, on the basis of already operational antennas, the wavelength of 18 cm was selected. By using this wavelength range, one can conveniently combine the radio astronomy observations of the objects with active nuclei, and the sources of maser radiation of hydroxyl lines, to handle a number of astronavigational problems, in particular such as the determination of trajectory of motion of the balloon in Venus atmosphere and of the delivery means - the planetary spacecraft - the Vega project (Sagdeev et al., 1986). The global radio interferometry network operates on this wavelength, and by using it, it is possible to provide the round-the-clock observations of the objects with a high degree of accuracy and reliability of measurements. Within this wavelength range the calibration and adjustment of radio interferometers has been simplified. The observation of maser sources which emit narrow hydroxyl lines with a specific circular polarization of radiation makes it possible to check out quite easily the polarization parameters of the receiving antennas, the proper operation of the transformation systems and systems of signal recording, the nominal accuracy of the received frequencies. By using the narrow and intense maser lines, it is easy to carry out the preliminary adjustment of the networks - to determine the relative position of the components and to synchronize the atomic clocks, and by using the quasars which are the sources of continuous radiation - to refine these parameters. A second wavelength will be introduced in the near future which will correspond to the maser radiation of the water vapor line at 1.35 cm.

Components of the network. The components of such network incoporate large, fully rotational parabolic antennas, located in the vicinity of Simeiz, Evpatoriya, Pushchino, Ulan-Ude and Ussuriysk. The size of antennas, their directional patterns ϕ_a, the surface utilization factors K, the effective surface areas A, the antenna noise temperatures T_a and the system noise T_s and the sensitivity fluctuation in the continuous radiation mode are presented in the table.

In conjunction with the use of low noise amplifiers, a particular attention was devoted to lowering the antenna noise temperatures - in all cases, it is below $20^\circ K$.

The reception of the 22-m antennas is brought about from the primary focus by the sectoral horns (Velikhov, 1985), which provide high utilization factor of the mirror surface K=0.57 (in Simeiz) and the antenna low noise temperature $T_a < 20^\circ K$.

The reception by the 25-m antenna in Ulan-Ude makes use of the Cassegrain design, in which the secondary mirror is of 4.3 m

diameter and may be viewed from the secondary focus at an angle of 34°. The shape of mirrors differs from the traditional paraboloid and hyperboloid shapes, facilitating the improvement in the antenna efficiency. The utilization of the sectoral horn and the slots with adjustable depth provide the wideband capabilities of the system. The coefficients of the antenna surface area utilization K=0.45, and the noise temperature $T_a \leq 20^{\circ}$K.

The most sensitive components of the network are the 70-m fully rotational, parabolic antennas (Aslanyan et al., 1986). the utilization of homologous design of the major mirror and high accuracy in manufacturing the reflecting surfaces provide high efficiency of the antennas, up to the shortest centimeter wavelength. At the 1.35 cm wavelength, the effective surface area of the antenna is 1500 m^2. The antenna employs Gregory type design of irradiation, making it possible to conduct the measurements from the primary focus in the decimeter range. The primary mirror is of quasiparabolic shape and the secondary one - is quasielliptic. The antenna irradiation is accomplished by using the corrugated horn with slots of adjustable depth. The horn directional patterns in E and H planes, in practical terms, completely coincide and at -20 db level, are equal to ~60°, which corresponds to the angle at which one can see the 7-m elliptical mirror. The effective antenna surface area at the 18 cm wavelength, while employing such irradiation pattern, is equal to 2730 m^2, which corresponds to the antenna utilization factor K=0.71. At the present time, to provide the functional operation and rapid change of the wavelength, the antenna mounts a rotating periscope two-mirror system, which can move the focal point to a distance of 1.5 m from the parabaloid rotational axis. Six exciters of multimode type are mounted along the circumferential perimeter. The effective surface area of the antenna at the 18 cm wavelength in this case is equal to 2200 m^2, which corresponds to K=0.57 (efficiency factor).

Site	ϕ_a	D,m	A,m^2	K	T_a	T_s	F,mJan.
Ussurisk	10′	70	2100	0.55	19	60	57
Evpatoriya	10	70	2200	0.57	18	50	45
Ulan-Ude	28	25	220	0.45	20	65	600
Simeiz	37	22	210	0.57	20	70	660
Pushchino	37	22	185	0.49	15	65 ·	700

The signal reception on antennas is being conducted in the left circular polarization. The identical polarizers are mounted on all antennas. They are in the form of elliptical waveguides and set up directly after the exciter. Such polarizer ensures the minimal losses. The antenna noise temperature, including the temperature of the sky, the Earth radiation and the scattering of the

directional pattern, the impedance losses in the antenna feeder circuit and the coaxial waveguide transition segment, as one can see from the table, does not exceed 20°K.   To exclude some additional losses, the low noise amplifier is coupled directly to the waveguide.

Equipment assemblies. The interferometer uses, within its input assembly, the low noise amplifiers of either parametric or transistor type, kept at liquid nitrogen temperature. Depending on the type of amplifier used, the radiometer noise temperature is either 30 or 40°K. As one can see from the table the total noise temperatures of all components within the interferometer system are in the range of 50-70°K.

The received signals, after amplification and transformation to f=167 MHz, are fed into the laboratory enclosure where they are additionally converted to the video bandwidth, limited in amplitude and then are recorded on magnetic tape in the international format Mark-2. The possibility to record both the direct and mirror channels at the video bandwidth from 15 to 2000 kHz is provided for. The frequency retuning is accomplished by using the frequency synthesizer, connected into the circuitry of the second converter. The multiplier which increases the frequency of the reference oscillator from 5 to 1500 MHz is used as the first heterodyne. The hydrogen frequency standard of Chl-70 type is used as a reference oscillator and its stability reaches 10^{-14} during the time period of about ~1000 s. It is also used as the time storage unit. The synchronization of times at the observation sites is accomplished by either using the signals of accurate service time, or in case of need, by transporting the atomic clock.

The handling of astronavigational problems is analogous to the determination of position of the source of space radio emission from a celestial sphere, but in this   case we are involved with the signal generated by the spacecraft transmitter. The simplest way of handling this problem is by the differential method, in other words the measurements of position are carried out with respect to the source of a radio signal with known coordinates (Kogan et al., 1985). At the present time, the position of many quasars is known with the accuracy of several milliseconds of arc. In order to exclude the ambiguity of radio interferometry measurements, the observations are usually conducted at different frequencies and one synthesizes a broad band either with the radio interferometers having bases of different length, or one synthesizes the "narrow" directional pattern. In the first case, in astronavigation, the transmitter must emit several frequencies. In our case, taking into account the ballistic data, we have utilized an additional two frequencies, at a distance from the central frequency of 3.25 MHz. In conjunction with this, the equipment assembly provides an additional channel, making it possible to report simultaneously on the video tape three signals

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which are frequency-converted to 0-25 kHz, 1.4±0.1 and 1.8±0.1 MHz, corresponding to the frequencies of the signals received, which are at a distance of 3.25 MHz with respect to the central frequency. In measuring the relative position of the balloon in the Venus atmosphere, the delivery spacecraft itself, once it launched the balloon, was used as the reference object.

In testing the components of the interferometer, it was shown /63 that their sensitivity corresponds to the calculated data. Figure 1 shows the results of the autocorrelation processing of the maser source ON 40.62-0.14 observations, which were conducted by using the 70-m antenna in Evpatoriya. The time of signal accumulation was 20 s, and the resolution in terms of frequency - 2.25 kHz. At the line maximum, the antenna temperature is $20^{\circ}K$, the radio emission density from the source in the line is equal to 12 Jan. It follows from this that the sensitivity fluctuation F=400 mJan. Such sensitivity makes it possible to receive the signals from the on-board transmitter within 1 Hz frequency band, having the power of 8 W, from a distance of 10^8 km, having the signal-to-noise ratio as per Figure 1. The subsequent readings from the delivery spacecraft (the power output P=45 W) and of the balloon (P≈5 W) which in June 1985 were at a distance of $110 \cdot 10^6$ km, have sub-stantiated these estimates. Figure 2, a and b, shows the signals emanating from the balloon and from the delivery spacecraft in 1 Hz frequency band, with the measurement time of 1 s. These graphs show the signal intensities rather than power outputs, as usual, and therefore, in order to compare them with the curve in Figure 1, it is necessary to square the count along the y axis. The sensitivity of the interferometer components operating in the continuous mode corresponds to the calculated data, as shown in the table.
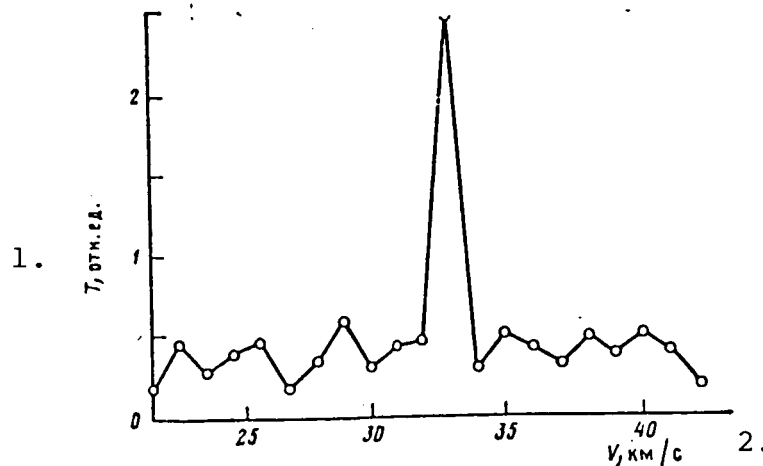

Figure 1. Profile of maser source OH 40.62-0.14 line.
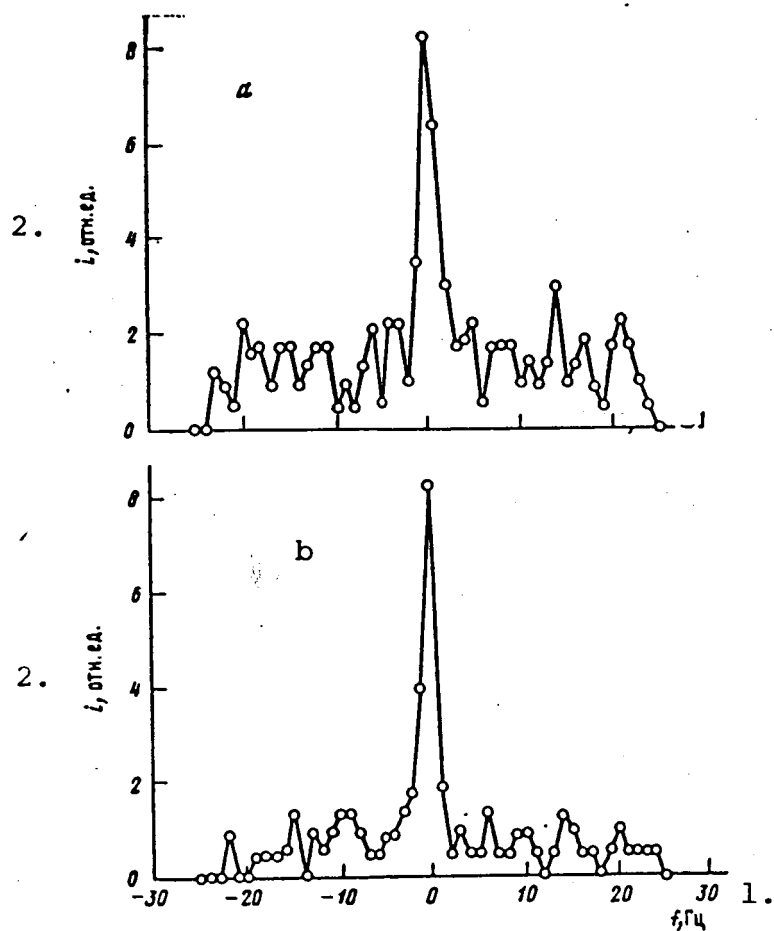
Key: 1. km/s; 2. T, relative units

Figure 2. Signal intensities from the balloon (a) and from the delivery spacecraft (b) within the framework of the Vega experiment.

Key: 1. f, Hz; 2. i, relative units

Parameters of the radio interferometry network. The components of the radio interferometry network, as one can see from the table, are distributed practically across the whole territory of the USSR. The maximum distance in the east to west direction is 7000 km, and in the north to south direction - 1300 km. The spatial frequency overlaps at the 18 cm wavelength for the ZS84 source are shown in Figure 3. The width of interferential lobes are between 0".006-0".4. The sensitivity fluctuation of the interferometer components makes it possible to study the quasar nuclei at the levels of several dozen milliJansky, even having the Mark-2 recording system. The great advantage of such network /64 is that the most sensitive components of it are at a maximum distance from each other. This makes it possible to investigate both the fine and intermediate scale structure of the radio source.

It is being planned in the nearest future to equip the antenna in Ussuriysk so that it could operate on the 1.35 cm wavelength, which will expand significantly the capabilities of the three-component interferometer (Matveenko et al., 1983). The minimal width of the interferential lobe in this case will be 500 μs of arc, which by coupling it to high sensitivity ($T_a=70^{\circ}$K, A=1500 m^2) opens up extremely broad avenues for the investigation of supercompact sources. It is also being planned to utilize within such network an additional number of large antennas.

In conclusion, the authors express their gratitude to the /65 coworkers of many organizations who participated in preparing and activating the radio interferometer network.
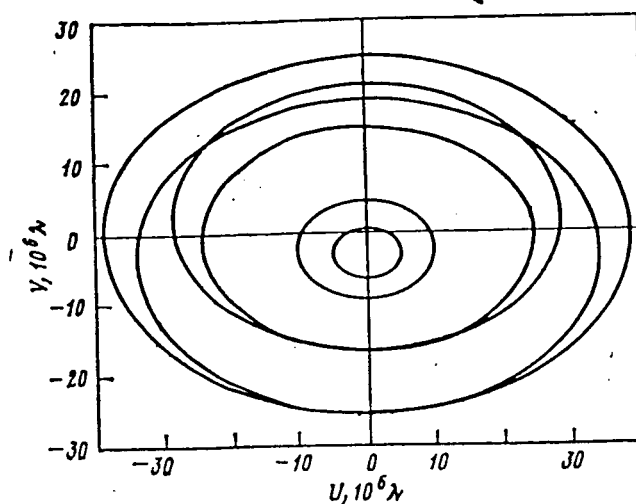
Figure 3. Spatial frequency network overlap on 18 cm wavelength.

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STUDY OF VENUS SOIL COMPOSITION IN THE NORTHERN PART OF APHRODITE TERRA BY USING VEGA 2 INTERPLANETARY LANDING MODULE

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The X-ray radiometric experiment in determining the   /66
elemental soil composition on Venus is being briefly des-
cribed. The experiment was conducted by utilizing the Vega 2
landing module. The preliminary data is presented on the
soil composition in the northern part of Aphrodite Terra. A
brief geochemical interpretation and the character of the
studied rocks is given.

The data about the composition of naturally radioactive elements
at the landing sites of the interplanetary spacecraft Venera-8, 9 and
10 (Surkov et al., 1973, 1976) and of the basic rock-forming elements
at the landing sites of the interplanetary spacecraft Venera-13 and
14 (Barsukov et al., 1982; Surkov et al., 1983 a, b, 1984) made it
possible to develop a certain idea of the nature of the rocks in
the smooth valleys and at the foothills which comprise altogether
about 4/5 of the total Venus surface. In terms of composition, the
rocks at all landing sites turned out to be similar to different
types of basalts, found in the Earth's crust.

What was not studied at all were the Venus surface areas of
high mountain land masses of Ishtar and Aphrodite Terra, where by
analogy with the Moon, Mars and the Earth, one could expect the
types of rock which would differ from basalts. This was precisely
the reason why the Vega 2 landing site was selected in the north-
eastern part of the Aphrodite Terra. The obtained data on rock
composition in this area supplements, to a certain degree, the
lack of data about the high mountainous regions of Venus.

We shall present below a short description of the experiment
for the elemental determination of the rock composition, conducted
by Vega 2 spacecraft and the preliminary data obtained in the course
of this experiment.

Method of measurements and the X-ray fluorescence spectrometer
assembly. The determination of the major rock-forming elements,
from Mg to Fe inclusive, and also of some heavier rare elements,
was conducted by the X-ray radiometetric method, by using the
equipment mounted on the landing module. This method is based on   /67
the relationship between the intensity of characteristic radiation
caused by the radioisotope sources as a function of the element

which is being analyzed in the probe. The method has been used successfully earlier in the studies of Mars and Venus.

In conducting the measurements, the instrument used was an improved modification of the X-ray fluorescence spectrometer which was functional on Venus-13 and 14. The assembly consists of two blocks: the detection block and the multi-channel pulse analyzer. The general appearance of the instrument is shown in Figure 1. Both blocks are placed into a air-tight temperature-controlled enclosure, within the landing module. The detection block has two separate sections: in the lower section, one finds the measuring cell and temperature sensor, in the central one - the electronics (preamplifier, amplifier, power supply), and temperature sensor and in the upper one - the pressure sensor.
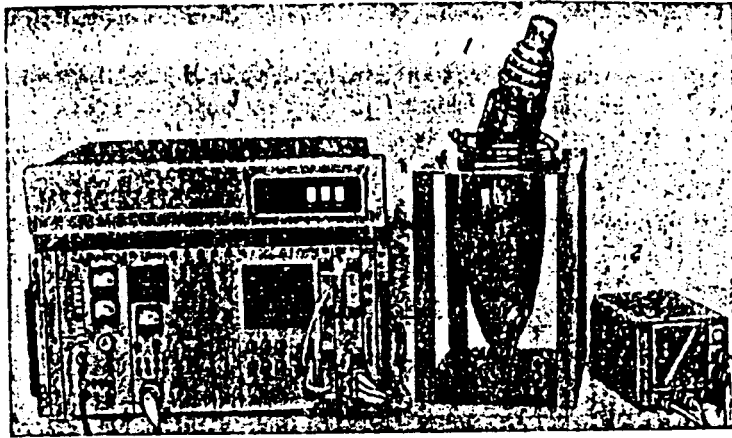

Figure 1. General view of X-ray fluorescence spectrometer which was used on the interplanetary spacecraft Vega 2: 1 is the detection block, 2 the pulse analyzer, 3 is monitoring and measuring equipment.

The measuring cell includes three radio-isotope sources (one plutonium-238 source and two iron-55 sources), four gas discharge proportional counters and the soil-handling device for the rock which is to be analyzed.

The detection block in which the soil-handling device and the rock are located is filled by dry nitrogen at 40 torr. pressure. The detection block schematic is shown in Figure 2.

The past experience of working with the X-ray fluorescence spectrometer on the interplanetary spacecraft Venera-13 and Venera-14 enabled us to introduce some changes in the instrument design, aimed at the improvement of its reliability, upgrading the instrumental analytical parameters and extending the range of the elements which may be analyzed, while upgrading the sensitivity of detection.

To improve the sensitivity of the detection of elements, the   /68 thickness of the beryllium windows in the counters was reduced from 50 to 35 μm and the intensity of radioisotope sources was increased. This made it possible to expand the range of the monitored elements.
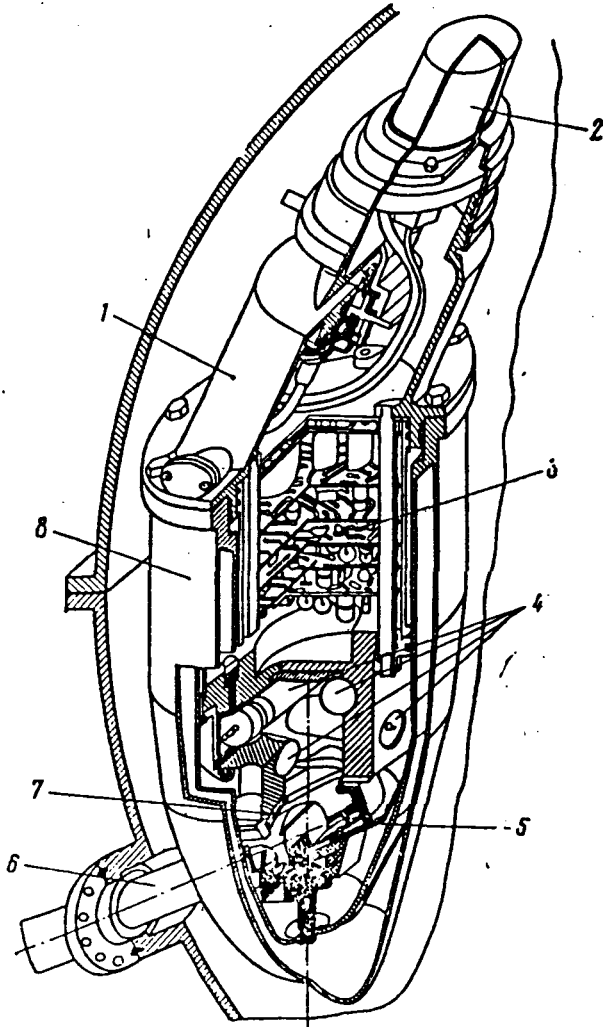
The assembly in-
corporated four counters,
three of which are filled
with 90% Kr + 10% CH_4 and <u>/69</u>
one which contained 90% of
Xe + 10% of CH_4. This last
counter has the range of
15-20 keV, making it
possible to detect the
heavy iron elements
(within the K series, the
elements starting with
Z - from 27 to 35, and
in L series, with
Z - from 79 to 83).
As one can see, by using
all counters, the in-
strument registers all
elements from magnesium
to bromine and from gold
to bismuth.

To check out the
analytical capabilities
of the instrument and to
evaluate the threshold
sensitivities in de-
termining these elements
and also in preparing the
multielemental spectral
library, a series of
measurements of different
rocks was tested, by
adjusting in them the
concentration of some
elements which had to be
analyzed. In the course
of such measurements, the
small incremental adjust-
ments of the oxide of a
given element were intro-
duced into the rock, having
either minimal or zero
concentration of the
element in question.

Studies on Venus
surface. The oper-
ation of X-ray fluores-
cence spectrometer on
Venus surface was accom-
plished, in accordance with

Figure 2. Arrangement of the de-
tection block in the X-ray fluores-
cence spectrometer: 1 - container lid,
2 - pressure sensor, 3 - compartment
for electronics, 4 - detectors,
5 - soil-handling device, 6 - conduit
to move the sample probe,
7 - radioisotope source,
8 - container.

the preassigned program. The instrument was activated at the height of 23 km above the Venus surface. In the course of 35 min, and all the way to touchdown on the planetary surface, the spectrometric calibration was conducted by running a set of background spectra, while the soil-handling device was empty. The time of spectrum-taking was 190 s. The schematic operational diagram of the spectrometer provided for sequential activation in pairs of two proportional counters of the four available, which were mounted within the detection block. Prior to touchdown of the module, it was possible to obtain six background spectra from each counter. Simultaneously with these spectras, a set of analogue parameters were recorded - the detection block and pulse analyzer temperature, the pressure inside of the analytical cell of the detection block and the integral rate of fluorescent quanta count in each counter. The accumulated data was transmitted to the Earth by means of telemetric channels.

During the first 172 s after landing of the module on Venus surface, the sample was obtained by drilling, using the soil-handling device, the removal of gaseous atmosphere surrounding the preselected sample, in other words, the lowering of pressure from 86 bar to 55 torr., necessary for the operation of the X-ray flouresence spectrometer, and transporting the sample through the internal conduit, inside of the landing module. During all these operations in delivering the sample to the analytical cell of the detection block, the background calibration measurements were continuing, with the goal in mind to establish the possible changes (scale shift, discimination, increase of pressure and temperature) in the work of the spectrometer, after landing. Once the probe of the Venetian rock was received by the soil-handling device, the spectral measurements of the excited X-ray fluorescence radiation were done and the readings were transmitted to the Earth by using the TM channels. Within the framework of the measurement geometry chosen, the rock sample was irradiated simultaneously by all sources and the excited fluorescent radiation was simultaneously incident on all counters. According to the cyclogram of measurements, after the sample was acquired by the soil-handling device, each counter /70 had executed five measurements of the X-ray fluorescence spectra of Venetian rock in the course of 190 s.

Figure 3 shows the spectra of Venetian rock sample, measured by two different counters.

Outline of the spectral analysis of Venetian rock. The spectral analysis of Venetian rock was conducted in the following manner. The intensity of measured spectral ranges was first corrected in order to correlate it with the scale used in the pre-flight calibrations. Then the position of spectral lines for the elements which were analyzed were defined.
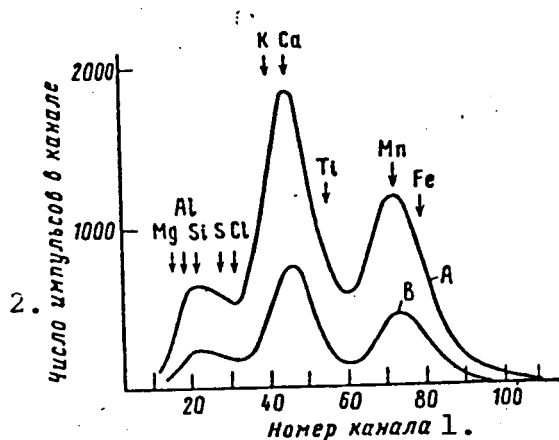
Figure 3.   Spectra of X-ray fluorescence radiation, emanating from the Venetian rock, measured on Vega 2 landing module by the nearest (A) and most distant counter (B).

Key: 1. Number of channel;
2. Number of pulses within the channel.

At the next stage, the corrections were introduced for ^{55}Fe decay, and the correlation analysis was carried out by using HICOR program using the instrumental library spectra which were taken by the instruments on Vega 2, and the major spectral library, where the measurements were taken on an analogue of the Vega 2 instrument. In comparing the spectra with the spectra of the major library, the difference in intensities of radioactive sources and efficiency of X-ray quanta recording were taken into account.

After conducting the analysis by using the HICOR program, the rocks were separated, the spectra of which agreed best with the spectra, measured on Vega 2. Then by using the program ITERA, the modification of the selected spectra for the standard rocks was carried out, until better agreement with the spectra of the analyzed rock was obtained. This stage is basically analogous to the method described by Barsukov (1985), Barsukov et al. (1979) and Surkov et al. (1984). However, the method of proceeding from the incremental reading of the analytical line intensity in the element which is analyzed to the incremental change of its concentration, has been some- what changed ΔI=f(ΔC). The ΔI=f(ΔC) relationship was previously determined by us, using the curves which defined the sensitivity factor S=ΔI/ΔC, which was obtained by diluting the oxide of the   /71 element in question in the neutral medium (Li_2CO_3). In this case, this relationship was determined by adding the oxides of the element in question to the rocks of different chemical composition. This made it possible to take into account the mutual effect, and to account more correctly for the effect of the coefficient of mass absorption, and related increase of the analytical line intensity as the concentration of the element in question changes.

Results of the experiment. As a result of the data processing obtained from the landing module Vega 2, the chemical composition of the Venus rock was determined. The preliminary data is shown in the attached table. The spectral comparison of this rock with the spectra of the major library, as per HICOR program (Surkov et al., 1983a) had shown that the best agreement is found as we look at the rocks within the Earth's crust of troctolite and anorthosite type, and rocks of similar composition. The subsequent, more detailed analysis of Venetian rock composition, with the utilization of iterations as per ITERA program (Surkov et al., 1983a) with the employment of data, defining the amounts of natural radioactive elements, as determined by the Vega 2 gamma spectrometer (Surkov et al., 1986) had shown that in the northern part of Aphrodite Terra we have encountered a rock which, in terms of its composition, is similar to the rocks of anorthosite-norite-troctolite group (ANT), which are extensively found on the lunar surface. (The descriptive composition data of ANT rocks is presented in the study by Barsukov et al. (1979)).

It is known that the lunar surface areas and probably also that of Mars, which are compsed of ANT rocks represent probably the preserved part of the primary feldspar crust which was formed during the accretion period, and soon after it (in other words, 4.6-4.3 billion years ago). The remaining part of these planet surfaces are represented by the basalt rocks which were formed at a later time, in other words 3.8-3.6 billion years ago (in the depressed surface areas), as a result of molten basalt flows (Barsukov, 1985).

As it appears, on Venus in the northern part of Aphrodite Terra, we are encountering the same old rocks of which the high mountainous region is composed.

CHEMICAL COMPOSITION OF THE ROCK AT THE VEGA 2 LANDING SITE

Element (oxide) Amount (wt. %)   Element   Amount (wt. %)

Element (oxide)	Amount (wt. %)	Element	Amount (wt. %)
MgO	11 ± 3.8	CaO	7.3 ± 0.7
Al_2O_3	16 ± 1.9	TiO_2	0.2 ± 0.1
SiO_2	45.6 ± 3.2	MnO	0.14 ± 0.1
SO_3	4.7 ± 1.5	Fe_2O_3	8.5 ± 1.3
K_2O	0.1 ± 0.08		

As we can see, one now gets a general idea about the types of magmatic rocks which are found in the major geological-morphological provinces of Venus, corresponding to defferent tectonic and magmatic stages of its development. These old highlands (the areas of interplanetary spacecraft Venera-8 and Venera-13 landings)/72 are composed of weakly differentiated alkaline basalts. The smooth depressions (the areas of Venera-14 landing) are covered by the volcanic tuff of toleite basalts and the young volcanic super-structures (in the areas of Venera-9 and Venera-10 landing), in terms of composition, as it appears, are also similar to the toleite basalts. Finally the high mountainous massifs (the site of Vega 2 landing), one may assume are also of the composition similar to the rocks of ANT group.

The knowledge of the chemical composition of rocks in these geological-morphological provinces, together with the evaluation of the relative age of these provinces on the basis of the crater densities, makes it possible even now to approach the understanding of the history of magmatism on Venus, and the chronology of events, resulting in the development of its surface and crust.

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WATER VAPOR CONCENTRATION IN THE VENUS ATMOSPHERE FROM VEGA 1, VEGA 2 PROBES

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Results of determination of water vapor concentration   /73
in Venus atmosphere from Vega 1, Vega 2 are described. The
measurements were carried out by means of the humidity ana-
lyzer VM-4 including two sensitive elements: thermal water-
absorbing detector based on LiCl for measuring temperature
of the condensation point (-30 to + 30)$^{\circ}$C and coulombmetric
detector for measuring volume water vapor concentration
(0.01-0.2)%. The ranges of water concentration measurements
by both detectors complement each other and partially overlap.
The instrument was placed on the landing module. The measure-
ments were carried out at the altitudes of 62-25 km above the
surface of the planet. Two vertical water vapor concentration
profiles were measured in the Venus night atmosphere.

The amounts of water vapor in Venus atmosphere have been de-
termined many times by the ground methods and from the interplanetary
spacecraft. In spite of this one observes a significant difference
in the results obtained by different methods and on different space-
craft, which indicates, as it appears, a change in the moisture
distribution in time and in terms of the altitude, and the com-
plexity of the problem of determining the water vapor in the atmos-
phere. The experimental results of measuring the moisture in Venus
atmosphere have been discussed in numerous articles and monographs
(Surkov et al., 1970; Volkov, 1983; Moroz et al, 1983; Hunten et
al., 1983) (Table 1).

To study the vertical profile of the water vapor distribution
within the cloud cover and in the troposphere, under the clouds,
the Vega 1 and Vega 2 carried the humidity analyzer VM-4, utili-
zing two methods of humidity measurements and employing two meas-
uring ranges, supplementing each other and overlapping.

This article will describe briefly the methods, equipment and
preliminary experimental results.

Principle of operation and intrumental design.   Figure 1
shows the general view of the humidity analyzer VM-4. The in-
strument consists of two blocks - the electron converter 1, and   /74
sensor unit 2. Within the sensor unit, utilizing a common base,
the coulombmetric and thermoelectrolytic humidity sensors were
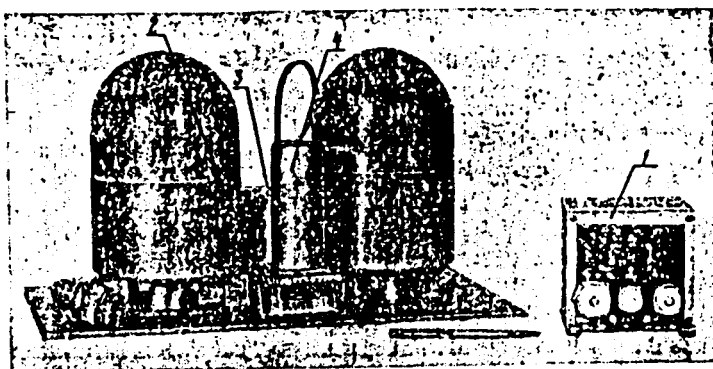mounted, as well as the sampling device 3 and contact switch 4.

Figure 1. General view of the humidity analyzer VM-4; 1 - electron converter, 2 - sensor block, 3 - sample-handling device, 4 - contact switch

The moisture sensitive component of the thermoelectric sensor is the heated humidity sensor based on LiCl. The principle of its operation is based on the relationship between the vapor pressure above the saturated salt solution and the temperature. The design of the moisture sensitive element and the principle of thermoelectrolytic sensor operation are described in detail in the study by Surkov et al. (1983). Figure 2 shows schematically the design of the thermo-electrolytic sensor. In contrast to the BM-3R instrument (Surkov et al. (1983) in order to provide the operation within a broad temperature range, the tube with the moisture sensitive element 8 and with the resistor type thermometer 10 are placed into the air-tight, temperature controlled enclosure, filled with $LiNO_3 \cdot 3H_2O$ (9), the temperature of the transition phase of which is close to $30^\circ C$. In addition, the instrument provides a special thermal insulation 11. The range of measured absolute humidities by the thermoelectrolytic sensor is 0.38-31.8 mm of mercury, which corresponds to the condensation point temperature from -30° to $30^\circ C$.

The principle of coulombmetric sensor operation is based on the electrolytic decomposition of water into hydrogen and oxygen and the incremental measurement of the volumetric hydrogen fraction in the gas. To decompose the water, one utilizes the coulombmetric tube 4 (Figure 2) on the interior of which, there are two platinum electrodes, in the shape of helixoidal spirals which make no contact. Between the electrodes, one applies a film of hydrated P_2O_5. The moisture which is contained in the analyzed gas enters the coulombmetric tube, is adsorbed by P_2O_5 and undergoes electrolysis, producing oxygen and hydrogen. To measure the incremental volumetric hydrogen fraction in the gas by such sensor, one employs the method of heat conductivity, since the hydrogen heat conductivity is significantly higher than the heat conductivity of other gases. The method is based on the reading of heat conductivity of the analyzed mixture as a function of the quantity of the component which is to be measured. On the

TABLE 1. QUANTITIES OF WATER VAPOR IN THE VENUS TROPOSPHERE ON THE BASIS OF EXPERIMENTAL DATA

Altitude range, km	Concentration of particles per 10^6	Method and descending module *
52–54	1600	EG, LM V-4
52	1000	MS, P-V
52	600	GC, P-V
52	200	SPh, LM V-11, V-12
54–50	500±200	SPh, LM V-11, V-12
50–46	2000±1000	TEGA, LM V-13, B-14
50–40	200^{+200}_{-100}	SPh, LM V-13, V-14
45	6000	MG, LM V-6
42	5200±80	GC, P-V
42	1000	MS, P-V
42	300	SPh, LM V-9, V-10
42–3.5	50^{+50}_{-25}	GC, LM V-11
40–20	100^{+100}_{-50}	SPh, V-13, V-14
37	300	EGA, LM V-5
30	170	EGA, LM V-6
22	1350±20	GC, P-V
22	1000	MS, P-V
22	60	SPh, V-11, V-12
22	67	MS, V-11

*Arbitrary designations: V-4, V-5 etc., are Venera-4, Venera-5, etc., GC is gas chromatography, MG stands for manometric gas analyzer ($CaCl_2$), MS is mass spectrometry, P-V is Pioner-Venera, SPh stands for spectrophotometry, TEGA stands for thermoelectrolytic gas analyzer (LiCl), EGA stands for electrolytic gas analyzer (P_2O_5).

basis of the incremental increase of hydrogen concentration, one can judge the concentration of water vapors. The sensitive element in the thermal conductivity sensor 2 (Figure 2) is the glass-enclosed platimum spiral 3, which has high temperature coefficient of resistance. Depending on the gaseous mixture, flowing around the sensitive element, its temperature and consequently its resistance will change.

The range of measurements by such coulombmetric sensor is 0.01-0.2%, in terms of volume. Just like in the thermoelectrolytic sensor, the coulombmetric sensor is provided with the thermal insulation by using $LiNO_3 \cdot 3H_2O$ (1) and a special thermal insulation 6.

Both sensors are mounted on a common base, and between them one can see the device for vacuum release 7.
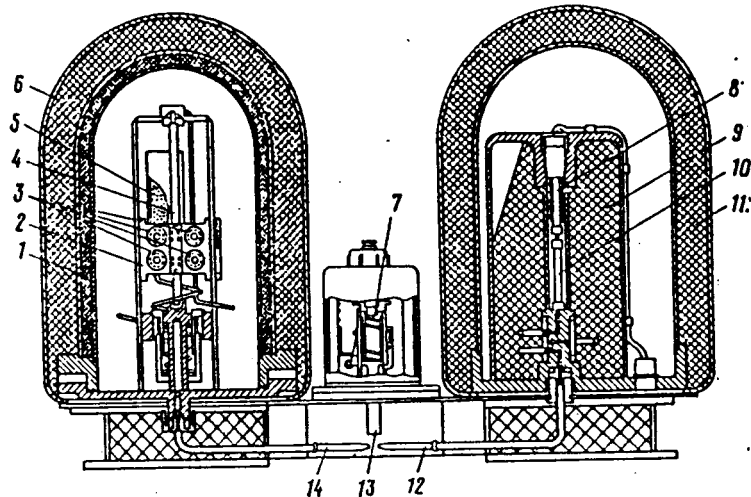
Figure 2. Thermoelectrolytic and coulombmetric humidity
sensors: 1, 9 - thermal insulation made of $LiNO_3 \cdot 3H_2O$;

2 - moisture sensitive sensor of heat conductivity;
3 - glass-covered platinum spiral; 4 - coulombmetric tube;
5 - cell P_2O_5; 6, 11 - special thermal insulation;

7 - vacuum release attachment; 8 - moisture sensitive
element in the thermoelectrolytic sensor; 10 - resistance
type thermometer; 12, 14 - glass tips; 13 - plunger for
vacuum release.

Prior to the launch, both sensors are thoroughly pumped out
and the cavity of the coulombmetric sensor is filled with dry air
up to the pressure of 20 mm of mercury, after which the glass tips
12 and 14, of the intake capillaries are fusion-sealed.

As the voltage is applied, the device 7 is activated, the
plunger 13 breaks the glass tips 12 and 14, and the analyzed gas,
driven by the excess pressure, enters the sensors. In the coulomb-
metric sensor the gas, after passing through the spiral part of
the tube designed for the gas cooling, enters the channel with two
sensitive elements 3, then enters the coulombmetric tube, the
second channel with the two other sensitive elements and into the
cell 5, filled with P_2O_5, in order to prevent the moisture entry
into the measuring block which may be desorbed from the interior
surfaces of the instrument. For the temperature control, within
the gas analytical block, and for the necessary correction in
readings, the external thermometer is provided. The signals from

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the gas analytical block outputs are amplified by the electronic amplifier and then are fed to the TM channels.

Preliminary experimental results. The humidity analyzers VM-4 were mounted in the lower part of the delivery device on the landing module. The activation of instruments was accomplished by the on-board programmed timer at the height of ~62 km from the surface. At that time, the sensor vacuum seal was broken and the power supply of the instrument was activated. From that /77 moment on the instrumental data was transmitted by means of TM channels at 2.3 Hz frequency. The results of operation of these instruments, mounted on Vega 1 and Vega 2 landing modules, and two vertical profiles of the water vapor distribution in the Venus atmosphere, on its nightside were obtained at the height range between 60 and 25-30 km. The distance between the landing sites of Vega 1 and Vega 2 landing modules was 1500 km. The preliminary results of measurements are presented in Table 2.

To obtain more detailed profile of the water vapor distribution it is necessary to thoroughly analyze all obtained data, taking into account the accurate readings of the pressure and temperature during the descent and the whole dynamics of the flight.

TABLE 2. AMOUNT OF WATER VAPOR IN VENUS ATMOSPHERE (Vol. %)

Height of the interplanetary spacecraft, km	Vega 1	Vega 2
55–60	0.2±0.05	0.05±0.03
45–50	0.1±0.03	0.1±0.03
25–30	0.02±0.005	0.012±0.005

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STUDY OF ULTRAVIOLET ABSORPTION IN THE ATMOSPHERE OF VENUS BY MEANS OF THE ACTIVE SPECTROMETRY METHOD

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Absorption spectrum of the atmosphere of Venus in the   <u>/78</u>
range (2300-4000)   Å was measured by means of the UV
lamp and grating spectrometer on-board the landuing
modules of Vega 1 and Vega 2 stations. The optical path
was ~170 cm. A broad absorption band without fine struc-
ture was found. Spectral and altitude dependence of the
absorption makes it possible to surmise that the main
absorbent is sulfur S_8 in the gas phase with the mixing
ratio (5-25) ppm (at the heights 25-40 km respectively).

In investigating the atmosphere of Venus, the spectrophoto-
metric probing was employed for the first time on the Soviet landing
modules Venera 11 and Venera 12, in 1978 (Ekonomov et al., 1979;
Moroz et al., 1979). The measuring instrument here was an optical
spectrometer, set up on the landing module. It was registering
the spectrum of solar diffused radiation, penetrating into the
deep atmospheric layers. The analysis of sequential spectra which
were recorded as the landing module was descending, made it possible
to obtain data about the quantities of some minor atmospheric com-
ponents, to learn about the properties of the aerosol component
and to obtain the data about the quantities of solar energy absorbed
at different altitudes within this wavelength range. In 1982, this
method in an improved variant was successfully used on the landing
modules Venera-13 and Venera-14 (Moshkin et al, 1983; Ekonomov et
al., 1983; Moroz et al., 1983).

In conjunction with the specifics of the flight geometry
toward Halley's comet, the Vega 1 and Vega 2 landing sites were
selected on the nightside of the planet. Therefore, it was proposed
by us to probe spectrophotometrically the atmosphere from these
modules, by the method of "active spectrometry," in other words to   <u>/79</u>
utilize the spectrometer with artificial light source and with an
optical design which would ensure the passage of the light beam
through the atmospheric gas. Naturally, such design may be effective
only for such spectral ranges in which the atmospheric gases have
high coefficient of absorption, and therefore we have selected the
range of 2300-4000 Å.

The Vega 1 and Vega 2 landing modules had on-board the
identical UV spectrometers ISAV, which were measuring the ab-
sorption of the gaseous atmospheric components in 2300-4000 Å range.

Outside of the module a collecting vessel of L≈0.85 m length (Figure 1) was placed, through which the atmospheric gas, being acted upon by the gaseous pressure, would be entering the assembly.

The stroboscopic pulse source was located inside of the air-tight compartment of the module and the generated light, passing through the module window, would pass through the external outlet, with the path being equal to double its length (1.7 m), is being absorbed by the atmospheric gases and returns back into the module compartment, entering the analyzing unit of the spectrometer. Within the analyzer, the formed spectrum (utilizing a concave holographic diffraction grid) registered the readings by using 512 silicon photodiodes. The nominal spectral resolution, corresponding to one element, was equal to $\Delta\lambda \approx 4$ Å. Aberrations and adjustment errors reduce the resolution by a factor of three.

One "complete" spectrum (512 elements in the range of 0.2–0.4 μm) is being stored in the instrument memory during 60 s, at the height h>25 km and during 36 s at h<25 km. In addition, each 4 s, a "surveillance" spectrum was generated by 16 elements and one element generates the numerical averaging out of the signals from 32 sequentially placed diodes. The instrument was activated at the moment when the module entered the atmosphere and was functioning in continuous mode during the whole descent of the module. The compressed data was transmitted to the Earth.
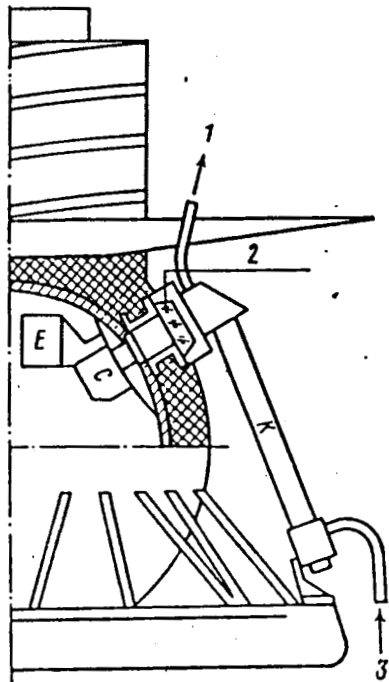

Figure 1. Schematic diagram of the UV spectrometer on the landing module. K is the external tube, C is the analyzer and light source, E is the electronic unit, 1 is the gas outlet, 2 is the bay window, 3 is the gas intake.

A characteristic feature of the instrument was the fact that its optical components are placed on both sides of the module wall, <u>/80</u> and therefore, some parts of the module – part of its enclosure, bay window and others, were incorporated as a part of the instrumental optical system, so that the instrument could be tuned immediately after the instrumental assemblies were placed on the module. The subsequent deformations of the module enclosure introduced some perturbations into the instrumental operation.

The data processing at this stage was conducted in the following manner: the first spectrum, obtained during the atmospheric entry, was used as "standard" spectrum E_0 (for which it is assumed that the absorption is absent). The Z spectrum, after landing of the module, was used as the "black" spectrum, corresponding to complete absorption. The passage of gas T, corresponding to the other spectra E, was defined as the following ratio.

$$T= \frac{E-Z}{E_0-Z} .$$

The empirical corrections for the temperature change in the components of the instrument were introduced by using the signal in the shortest wavelength range, where the source practically does not generate any emission. The empirical correction for a possible drift of parameters in the analyzer were also taken into account by introducing one integer parameter C, characterizing the possible spectral shift E (within the components) with respect to the spectrum E_0 in the course of descent. The optimum level of C parameter was determined on the basis of minimum overshoots, corresponding to the lines in the spectrum of the source. The C parameter preselected in such a manner was fluctuating from 0, at the beginning of descent, to 4-6 at the end.

The processing of "surveillance" spectra was reduced to the paired averaging-out and subtracting of the 16th ("black") signal component from the 15 first signal components of the "surveillance" spectrum.

The spectrometer functioned normally on both modules, from the moment of their activation, all the way to the landing. The spectrometric parameters practically did not differ from those obtained during ground tests. Each module has generated approximately 30 spectra, completely resolved, and 450 spectra of low resolution. The sequence of spectra (if one is to exclude sharp changes during the first 60 s of operation (and related overloads during the atmospheric entry) is characterized by small (and proportional at all wavelengths) signal increase up to the height of approximately 55 km, and then monotonic decrease as the module altitude was dropping. At the height of about 10 km, the signal from the source disappears completely and the voltages on the photodiode outputs, measured on the surface of the planet, are similar to the "black" level, measured on the Earth prior to the launch.

Figure 2 shows the examples of fully resolved spectra, obtained at different heights by Vega 2 (they are approximately the same in the case of Vega 1). Their main interesting feature is a

broad absorption band, the first traces of which appear at the height of about 55 km. The absorption peaks out sharply by descending from 50 to 40 km height, then decreases somewhat and then remains almost constant.

In planning for the experiment, it was assumed that the most important absorbing gas in this wavelength range is SO_2. Figure 2 shows a synthesized spectrum, calculated on the basis of such an assumption. One can clearly see that the band shape, recorded during the experiment is totally different. The absence of structure which is characteristic for SO_2 indicates that in the case of this unknown absorbing gas which produces the observed band, the product of cross-sectional absorption σ (cm^2) and the amount of this gas, is significantly larger than in the case of SO_2. The cross-sectional absorption of SO_2 on the basis of which the synthesized spectrum was generated, was taken at room temperature. We have compiled the data from various sources (including the data by Brassington, 1981). At this time, it is being planned to measure the SO_2 absorption spectra at high temperatures. The qualitative data as to the nature of the band at the temperature of about $470^{\circ}K$ is already available and it indicates that the general shape of the SO_2 band differs only slightly from the one obtained at normal conditions. Consequently, the spectral absorption band in Venus atmosphere belongs to some other gas.

The question of the identification of this gas has not been resolved as yet. As a working hypothesis, one might identify it with the allotropes of free sulfur in gaseous phase (S_n, where $2 < n < 8$). At the $455^{\circ}K$ temperature, which corresponds to 35 km altitude, a considerable part of sulfur must be in S_8 form. Figure 2 shows a synthesized spectrum, calculated on the basis of cross-sectional absorptions of S_8, measured in its gaseous phase, and in solution (Bass, 1953, and some of our own measurements). One can see that S_8 may approximately explain the observed spectral absorption, although there are some noticeable differences in 3300-3800 Å range. The spectral absorption data of some other allotropic sulfurs is quite scarce.

The S_3 and S_4 spectra (Meyer et al., 1971) differ strongly from the observed one. There is almost no information about S_5, S_6 and S_7 spectra. The S_2 absorption spectrum (Meyer et al., 1971) has fine structure which has not been observed by us. At the present time, the new laboratory studies are being done to refine the spectroscopic parameters of free sulfur.
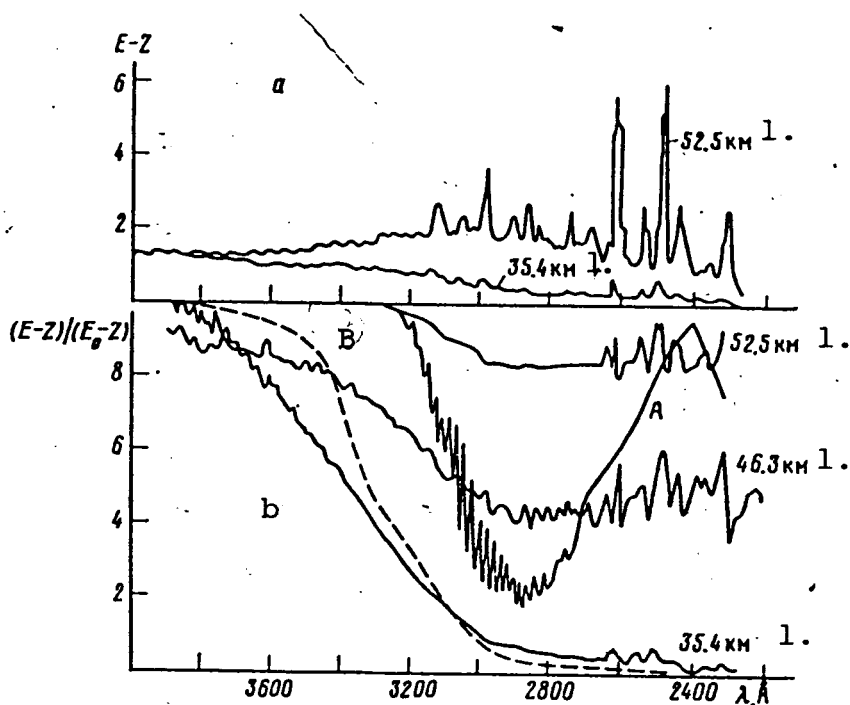
C·∂

Figure 2. UV absorption within deep atmospheric layers of Venus, based on Vega 2 data: a - radiation spectrum of xenon source (E-Z, see the text) with the optical path 170 cm long through the atmosphere, at two altitudes (which are shown), b - the $(E-Z)/(E_0-Z)$ ratios (the residual fine structure is the result of incomplete compensation of the relative λ shift in different spectra). The curve A is the synthesized SO_2 absorption spectrum (110 ppm-35 km), B is the synthesized S_8 absorption spectrum (15 ppm-35 km).

Key: 1. km

Because the particles of sulfuric acid are incorporated within the cloud cover, it may be assumed that the acid vapors must be present at the heights of 30-35 km in relatively large quantities (100 ppm, see for example Craig et al., 1983), and it would be interesting to make the comparison between the observed spectrum and the absorption spectrum of these vapors. We have not found in the literature any interesting data and one of the authors (A. P. Ekonomov) has measured in the laboratory the absorption spectra of H_2SO_4 at the temperature of about 420°K. According /83 to the results of these measurements, the sulfuric acid vapors may produce only a slight contribution to the observed absorption.
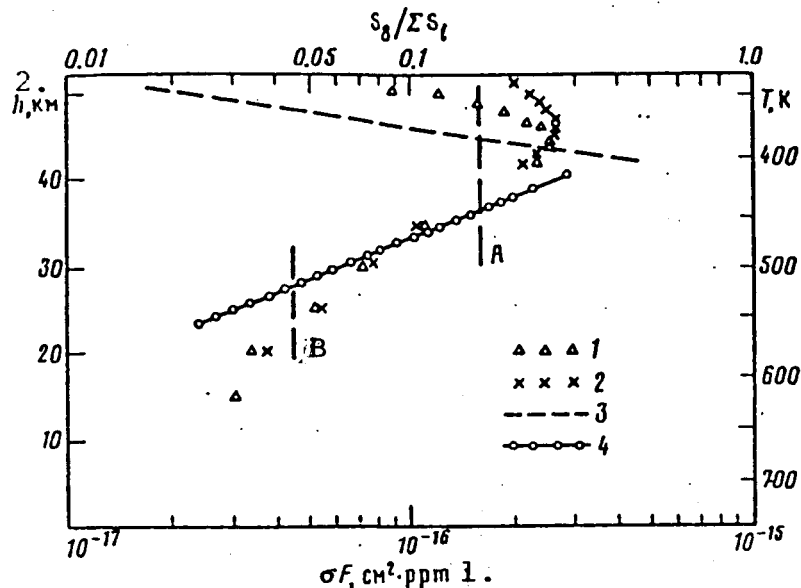
Figure 3. σF parameter as a function of h for the group of reception elements at the average wavelength $\lambda=3070$ Å (on the basis of "surveillance" spectra). 1 - Vega 1, 2 - Vega 2, 3 - σF curve which corresponds to sulfur saturation, 4 - $S_8/\Sigma S_i$ fraction at low partial sulfur pressures, estimated on the basis of Mills data (1974); A is σF level for S_8 at F=15 ppm, B is σF level for SO_2 and F=110 ppm.

Key: 1. $cm^2 \cdot ppm$;   2. km

Many other molecules in addition to sulfur were considered as possible candidates in the identification work. Among these, only the sulfanes H_2S_n, when $n \geq 2$ and chlorinated sulfanes S_nCl_m have the spectra similar to those observed, but they, as it seems, are unstable in Venus atmosphere.

If S_8 produces a domineering contribution to the absorption at $\lambda \sim 3000$ Å, the amounts of this molecule must be sufficiently large: from 5 to 25 ppm at 25-45 km, respectively. This is higher by two orders of magnitude than it was suspected earlier on the basis of indirect estimates, based on the spectrometry in the longer wavelength range (San'ko, 1980; Moroz et al., 1983).

In trying to identify the absorbing gas, one must take into account not only its spectral properties, but also its thermo-dynamic parameters. We can show that S_8 will approximately satisfy such criterion. Regardless of the nature of the absorbing

gas, the product of cross-sectional absorption σ and the ratio of F mixture is equal to:

$$\sigma F = \frac{10^6 \ln(I/I_0)}{LN} \ cm^2 ppm,$$

where I, I_0 are the intensities, in the presence and absence of absorbing gas, L is the length of optical pathway, N is the total numerical concentration (cm^{-3}). Figure 3 shows the altitude change σF for both landing modules, obtained on the basis of "surveillance" spectra of low resolution at 3070 Å wavelengths. The same figure shows the curve of sulfur saturation and the fraction of S_8 with respect to all other allotropes. The comparison of these curves indicates that the observed σF parameter, as a function of altitude, agrees approximately with the constraints which are imposed by the condensation and by the thermochemical equilibrium between the sulfur allotropes, although the agreement in this regard is not complete (the condensation curve is somewhat below the one which was measured).

The analyses of the experimental results are only at the initial stage, and it is likely that other variants will be found for identification.

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PRELIMINARY RESULTS OF THE VEGA 1 AND VEGA 2 OPTICAL INVESTIGATION OF AEROSOL IN THE ATMOSPHERE OF VENUS AT 30-60 km

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L. V. Zasova and A.P. Ekonomov

The concentration profiles of aerosol particles by using   /85
the aerosol spectrometer were obtained at the landing
sites of Vega 1 and Vega 2. Approximately the same alti-
tude regions were substantiated as in the case of the
preceding experiments: the major three-layered cloud
cover, the intermediate zone and the haze below the cloud
cover. There are, however, considerable quantitative
differences in the concentration of particles, particularly
in the size range distribution. The tropospheric night-
glow was detected at the wavelength of about 1 µm. The
backscattering coefficient and extinction coefficient
change only slightly at the altitudes between 63 and 32 km.
As it appears, a large number of submicron particles are
present in the atmosphere, above the landing site.

The instruments ISAV-A, identical in design, were mounted on
Vega 1 and Vega 2 landing modules, which were designed to study
the aerosols in the Venus cloud cover. The task was to determine
the numerical concentration of the aerosol particles along the path
of descent, the shapes of the particles and change in the back-
scattering coefficient. The direct range determination of the
particle size in Venus clouds was conducted earlier just once,
from a large probing spacecraft Pioneer-Venus (Pioner-Venera)
(Knollenberg and Hunten, 1980).

1. Methodology of measurements. The instruments used in
measurements consisted of two functional blocks - the photoelectric
aerosol spectrometer and the backscattering sensor. The aerosol
spectrometer operation is based on the measurement of the light
beam, scattered in four directions by separate aerosol particles,
passing through the instrument. The backscattering sensor measures
the light, scattered within a certain region by the aerosol medium,
in the vicinity of the instrument and/or the atmospheric glow.   /86
The instrumental schematic is shown in Figure 1. The light from
halogen incandescence source 1, of 5 W power, is being directed
by means of a mirror system 2, into the so-called "count volume",
in other words, into a specific area in space in which the light
scattering by the aersol particle is being measured. The size of
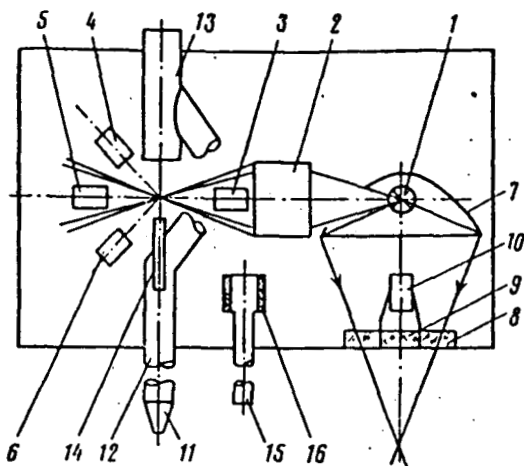of the "count volume" is about 1 mm^3.   A part of the scattered

Figure 1. Schematic diagram of the optical aerosol analyzer ISAV-A.

light, moving forward, backward and in the lateral direction (with the corresponding angles of scattering being equal to 7°-17°, 165°-175°, 25°-65°) are received by four optical-electron units 3,4,5 and 6, which utilize the silicon avalanche photodiodes as receivers. The two lateral sensors operate with similar angles of scattering, but at different azimuths.

The backscattering sensor is located within the general enclosure of the aerosol spectrometer. The light from the source 1 is reflected by a reflector 7, and through the window 8 into the atmosphere. A part of this light which is scattered in the atmosphere in the reverse direction (the 160°-175° angle) enters the instrument through the window 9, and is handled by the optical-electron unit 10. The effective operational volume of the back-scattering sensor is 5 cm^3 and the distance from its center to the window is about 3 cm. The source 1 is turned off periodically and at that time, the backscattering sensor records only the ex-ternal, background radiation, in other words, it operates as a photometer.

The photoreceivers with the appropriate electron circuitries are located in the air-tight part of the sensor unit and the latter is mounted on the circular support frame of the landing module, the optical components are located within the section of the same unit which is not air-tight and the signal processing is done within the unit which is located inside of the landing module.

During the passage of particles, the pulses on the outputs of four photodiodes of the aerosol spectrometer, are handled and processed logarithmically and the maximum values of each pulse are stored in the instrument memory until the passage of the next particle. Two times during each telemetry frame session (0.43 s), the request is made for the read-out, and the message   /87 transmitted to the Earth includes each time the amplitude of four pulses which characterize the indicatrix of scattering of each separate particle.

The instrument incorporates a 64-channel amplitude analyzer, on the input of which, via the logarithm converter, all pulses from one of the photodiodes which measures the scattering in the

lateral direction, are being fed. The analyzer is designed to
determine the sizes of all particles passing through the instrument
during the time of signal accumulation, which is equal to 27 s.
The data contained in the analyzer cells is being transmitted to
the Earth with the same periodicity. The instrumental dynamic
range in terms of the pulse amplitude is 10^4.

The particles are introduced into the "count volume" as the
gas rapidly flows during the module descent, by employing an
aspirator (Figure 1), consisting of coaxially-placed input tip 11,
oriented downward, in the direction of descent, the transfer tube
12 joined to the manifold 13 and capillary tube 14. To create the
aerodynamic focusing, the purified air from the surrounding en-
vironment is fed through the manifold 15 and   aerosol filter 16
into the instrument.

In calibrating the aerosol spectrometer, we have utilized the
particles of 0.5 to 6 μm in size, generated from the polystyrene
and the melamine-formaldehyde resin. On the basis of such cali-
bration and by utilizing the calculated extrapolation, based on
the size and on the refraction factor, the curves were constructed,
defining the output signals from all four channels as a function of par-
ticle size and the backscattering signal as a function of the coefficient
of refraction. The instrumental functions, determined during the
calibration (the measured sizes of monospectral dispersed particles)
turns out to be sufficiently narrow - the half-width was equal to
20% for the particles of >0.8 μm size. The measuring error for the
same size of particles was about 30% and increases quite rapidly
with the decrease of particle diameter.

The instruments functioned normally from the moment of the
bottom hemisphere removal (H=63 km) down to the altitude of 30 km
(Vega 1) and 32 km (Vega 2) during the time period of 20 and 18
min, respectively. During this time period, in all, 43 and 38
particle size spectra were transmitted as well as the indicatrices
of scattering for approximately 5000 particles.

Below are the results obtained during the initial stage of
the data analysis.

2. Numerical concentration of particles. Figure 2 shows the
profiles of numerical concentration of particles, obtained from
this amplitude analyzer on both modules. One can isolate several
specific zones which have been observed in the course of previous
experiments (Ragent and Blamont, 1980; Knollenberg and Hunten, 1980;
Marov et al., 1976, 1979, 1983): D - is the zone of high concen-
tration of particles above 55 km, C - is the zone of low concen-
tration of particles in the range between 51 and 55 km, B - is the
zone of high concentration of particles below 51 km, F - is the
"subcloud haze," A - is the intermediate zone between zones B and F.

The boundaries and size of these zones have been changing somewhat (particularly, the size of zone A). On the left, the boundaries of these zones are based on the studies by Knollenberg and Hunten, and to the right - in accordance with the data of our /88 experiment. To emphasize the difference, we have added in the latter case, to the letter designations, also the numerical indices. In the case of each of the zones A_1, B_1, etc., we have determined the averaged-out sizes of the spectra.

The height of about 48 km was usually defined as a sharp lower boundary of the main cloud cover. One can see from Figure 2 that the character of this boundary is strongly dependent on the particle size, on the basis of which the profile has been constructed.

The profile of the particle concentration of $D \gtrsim 0.4$ μm diameter extends through the intermediate zone A_1 with a relatively smooth concentration decrease, but if one leaves out the larger particles ($D \gtrsim 1.5$ μm), then the intermediate zone turns out to be considerably more narrow and the concentration on its lower boundary changes much more sharply (Vega 2) or the zone does not show up at all, merging with the zone F.
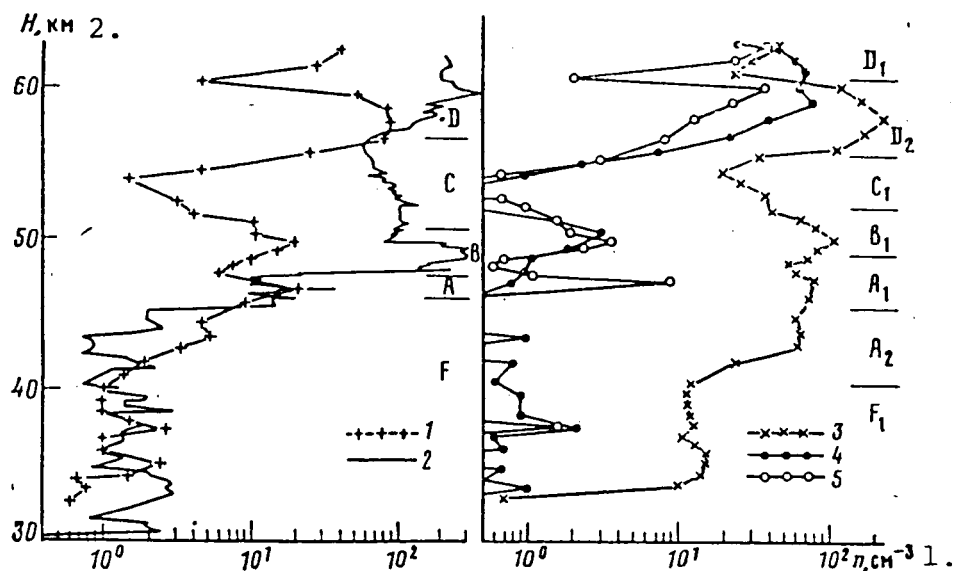

Figure 2. Profiles of numerical concentration of aersol particles in Venus atmosphere, based on the space module data: 1 - Vega 2, all particles are of $D > 0.7$ μm diameter; 2 - Pioneer-Venus, $D \gtrsim 0.6$ μm (Knollenberg and Hunten, 1980); 3 - Vega 2, $D \gtrsim 0.4$ μm; 4 - Vega 1, $D \gtrsim 1.5$ μm; 5 - Vega 2, $D \gtrsim 1.5$ μm.

Key: 1. cm^{-3}; 2. H,km

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As an example, Figure 3 shows the distributions found for D_2 and C_1 zones. The distribution for D_2 zone may be represented in its first approximation as follows

$$n = \text{const } D^{-4},\qquad\qquad(1)$$

where D is the particle's diameter.

In the case of Vega 1, the analogous distribution is also obtained for the zone C_1, but in the case of Vega 2, one observes a second maximum in the range of 2.5-4 µm, in other words, as it appears, the distribution features two modes. Let us note that in the zone B_1, the spectrum also displays a superposition of a separate mode of comparatively large particles, with the distribution of (1) type. This corresponds partially to the situation as determined by the large probe from Pioneer-Venus (Knollenberg and Hunten, 1980) but there are also considerable differences. Let us remind the reader that in the above-mentioned study, three modes were isolated: the first one which had the spectrum similar to (1), the second one - with the maximum at around 2.5-3 µm and the third one, at the altitudes of 48-58 km, had the maximum of about 7 µm.

In contrast to this data, in our measurements, the large particles of 5-15 µm diameter were detected only in the zone D_1. In addition, in our case, our total numerical concentration of particles is somewhat lower, exceeding a specifically assigned diameter within the B, C, D zones.

In our spectra, the mode 2 is much weaker and mode 3 in zones C and B cannot be seen at all. There are two possible explanations for this: a) there may be an actual difference in the sizes, in different parts of the planet, or b) the aerodynamic separation of large particles in the instrument which resulted in the decrease of their relative concentration inside of the instrument with respect to free space. The calculation of aerodynamic parameters indicates that the effect should be reversed, in other words, it should result in the increase of relative concentration of large particles. The corresponding calculation correction which is a /90 factor, changing between 1.1 and 4, depending on the altitude and on the particle size, has been introduced into our data. At the present time, the model experiments are being conducted to refine and recalculate this factor with respect to the free space, after completion of which, the results, if it will become necessary, will be corrected.

The numerical concentration and general profile outline for the particles with the diameter greater than 0.4 µm, obtained independently in the experiment related to the particle count, on Vega 1 and
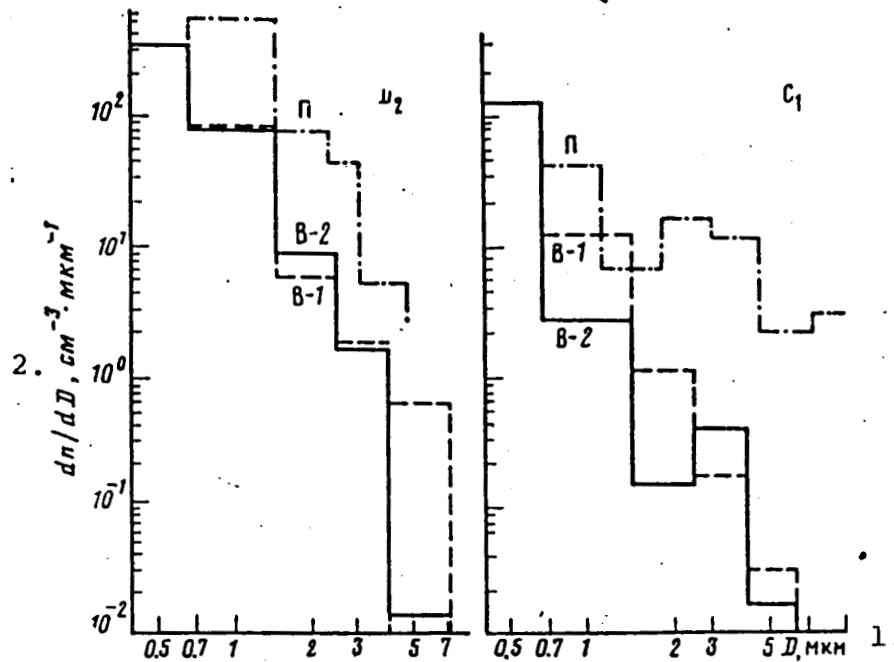
Figure 3. Examples of the averaged-out spectra of particle size. The solid line is Vega-2, zones C_1 and D_2, the dash line is Vega-1 and the same zone, and the dash-and-dot line is Pioneer-Venus, zones C and D. (For the altitude boundaries of the zones, see Figure 2).

Key: 1. μm; 2. $cm^{-3} \cdot \mu m^{-1}$

Vega 2, by using the instrument LSA, approximately agree with our results.

3. Shape of particles and the corresponding coefficient of refraction. The analysis of scattered light by separate particles in four directions enabled us to evaluate the shape of the particles and to determine their coefficient of refraction. During the flight of a spherical particle, the signals from both side channels will be the same. If, however, the particle shape differs strongly from the spherical one, then the relationship between the signals will depend on the particle orientation and will change from one particle to another. In the case of spherical particles, the coefficient of refraction may be determined on the basis of the signal relationship within the backscattering channel (with a strong dependence on the coefficient of refraction) and the comparison of such signals with the signals from any of two side channels (where the dependence on

the coefficient of refraction is practically absent).

In the case of the particles of more than 1 μm in diameter, the ratio of signals from two side channels is close to unity, and consequently, these particles are spherical. As the particle size decreases, the ratio of the above-mentioned signals differs quite significantly from unity. The coefficient of refraction, as determined for the particles larger than 1 μm, turn out to be equal to 1.4±0.1.

4. Coefficient of backscattering. Figure 4,a, shows the coefficient of backscattering σ_{170} as a function of altitude, as measured on both descending modules by the backscattering sensor. The zonal structure of the altitude-related distribution is displayed here much weaker than in the case of the numerical concentration profiles, although some traces of it may be found.

A surprising fact was large σ_{170} in the F zone. We have considered two working hypotheses which might explain this fact: the scattering by very small particles (D≈0.1-0.3 μm) which are beyond the sensitivity range of the spectrometer, and the scattering by very large particles (D≈0.1-1 mm). The first hypothesis requires the concentration on the order of 10^5 cm^{-3}, with the coefficient of refraction m≈1.5 and 10^4 cm^{-3} when m≥2.

The hypothesis of very large particles results in an unacceptable large mass density of the aerosol medium at D≈1 mm, and if D≈0.1 mm, the required concentration would turn out to be too high (~0.1 cm^{-3}) and also such particles must be detectable by the spectrometer if one is to disregard the assumption that the on-board equipment, located on the outside of the module, filters these particles out.

5. Nightglow of the troposphere. As the light source was shut off, the backscattering sensor has recorded considerable radiant flow from below, emanating from Venus atmosphere, in spite of the fact that the experiment was conducted in the middle of the night (the solar descent below the horizon was 79°.3 and 74°.0 on Vega 1 and Vega 2, respectively). As the module was descending lower and lower, the magnitude of this radiant flow was increasing.

As it appears, the most likely cause for such background radiation would be the surface thermal radiation, penetrating from below, through the atmospheric optical window at the wavelength of about 1 μm. As has been shown in our preceding experiments (Ekonomov et al., 1979; Moshkin et al., 1983) the presence of such a window has been established. The absolute levels of the background radiation brightness are determined by the backscattering sensor with the accuracy up to the level of the coefficient on the order

of 3. Let us note that the nightglow of Venus troposphere has also been recently discovered from the observations from the Earth (Allen and Crawford, 1984) in the spectral region λ~2 μm, which is apparently of analogous origin and this is most likely the thermal radiation from the surface and from the lower atmosphere which "creeped through" by passing the appropriate optical windows. The glow in the region around 1 μm has also been observed by optical sensors on the Vega 1 and Vega 2 modules.

The measurements which were conducted earlier during the daytime indicate that the true absorption within the "window" range at the heights of H>35 km may be disregarded and that the attenuation of emanating radiation from below is due here primarily to scattering. In this case, the one-dimensional approximation of medium (Sobolev, 1956) gives us a simple relationship between the altitude-related derivative of brightness and the coefficient of extinction

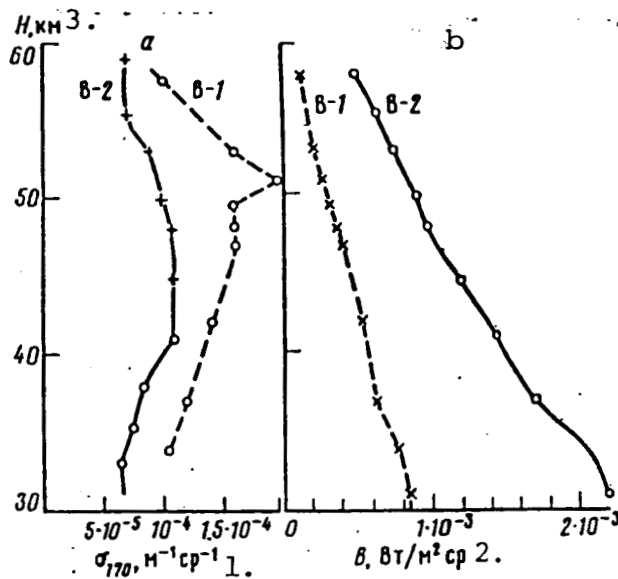$$\sigma_{4\pi} = -\frac{dB}{dH}\frac{2+\tau_0}{B_0},$$

(2)

where B_0 is the source brightness, τ_0 is the total optical thickness of the scattering medium. If we assume that the effective optical thickness of Venus atmosphere (in other words, the thickness, reduced to the isotropic scattering)

Figure 4. Results of measurements, conducted by using the backscattering sensor: a - coefficient of backscattering σ_{170}; b - intensity of the tropospheric nightglow B. The dotted line is Vega 1 and the solid line is Vega 2.

Key: 1. $m^{-1}sr^{-1}$; 2. $W/m^2 sr$; 3. km

at the wavelength of 1 μm $\tau_0=10$, then $\sigma_{4\pi}=10^{-4}$ m^{-1}. In order to correlate the $\sigma_{4\pi}$ and σ_{170} qunatities (the ratio here must be ~10), it is necessary to assume that either the brightnesses in reality were higher by one order of magnitude, or that during the time of measurements, there was a considerable true absorption at the heights H<30 km, with the additional attenuation factor of ~10.

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Putting aside the question as to the causes of the above-mentioned disagreement, let us note that a considerable contribution to the true absorption at the heights H>30 km, seems to be rather unlikely and a smooth change in brightness as a function of altitude, below the range of 45 km, may be viewed as an independent argument, favoring higher optical densitiy of the "subcloud" haze.

Let us remind the reader that in the history of optical studies of Venus atmosphere, there was another case where the high coefficients of extinctions were observed in A and F zones - this was the very first experiment, involving the brightness measurements which was conducted on Venera-8 in 1972 (Avduevskiy et al., 1973). After these measurements and during several subsequent years, it was assumed that the lower boundary of the major cloud cover is at the level of 35 km. These measurements were conducted in the vicinity of the morning terminator.

The measurements conducted by Vega 1, Vega 2 and Venera-8 enable us to assume that at steep angles of solar descent (at night and at dusk) the increased density of "subcloud" haze may be a frequent phenomenon. At the same time, the two night nephelometry profiles, obtained by the small Pioneer probes (Ragent and Blamont, 1980) show the low denisty of the "subcloud" haze also during the daytime measurements (in all, there were eight measurements). As it appears, at the nighttime and at dusk, there is an increased tendency for variation in the parameters of "subcloud" haze. The separate layers of increased concentration of particles, located at relatively low altitudes, have also been observed during the daytime (Venera-9, 10, Marov et al., 1976), Venera-11 (Marov et al., 1979).

6. Conclusions. 1) The vertical structure of the particles concentration profile at the landing sites of Vega 1 and Vega 2 modules may be described qualitatively by the same representations as to the altitude zones which were obtained for the dayside of the planet: the "three-layered" major cloud cover, the intermediate zone and the "subcloud" haze, with the lower boundaries approximately at the heights of 45-48, 42-45 and 32-35 km.

2) The concentration of particles with the diameter range between 0.7 and 10 µm at the altitudes above 45 km and particularly, the relative amounts of larger particles within this range, is lower /93 than at the landing site of Pioneer spacecraft.

3) The particles of D>1 µm diameter are spherical and have the coefficients of refraction 1.4±0.1.

4) In Venus troposphere, at the height of 63-30 km, the night-glow was discovered at the wavelength of about 1 µm, the origin of

which is probably the hot surface of the planet.

5) The coefficients of backscattering and extinction change only slightly across the whole altitude range between 63 and 32 km, where the measurements were taken, and practically display no vertical structure which would correspond to the concentration profile.

6) The results as formulated in points 1, 2 and 5 indicate the presence in the atmosphere, above the landing sites, of the submicron particles of high numerical concentration ($\sim 10^4$ cm^{-3}).

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16. Abstract

An overview of the VEGA probe to Venus is given, including a detailed examination of the baloon experiment to study the atmosphere of Venus. The areas of study include the ground network, the global network of radiotelescopes, meteorological measurements, the thermal structure of the Venus atmosphere in the middle cloud layer, atmospheric dynamics, and other results of the VEGA 1 and 2 experiments.

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