FORCED-INFLATION PARACHUTE FOR ROCKET PAYLOAD RECOVERY

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ABSTRACT

Parachute with forcing inflation was developed for saving and rapid braking in the mesosphere the Russian meteorological payload MERA from the altitude 100 km. Parachute provides the descent rate about 300 m/sec at the altitude 70 km which is necessary for reliable operation of the flight rocket instruments. Lower 30 km parachute provides the descent rate about 10 m/sec. By tracking the parachute descent lag the wind components are calculated. Parachute together with rocket instruments are rejected from the rocket cruise stage at the top of flight. Simultaneously the system of forcing inflation begins to operate. Description of saving system operation as well as the technical specification are presented. Such type of parachute with forcing inflation could be used for saving the heavy payloads and rocket engines.

INTRODUCTION

Russian meteorological rockets fulfill direct temperature measurements in the stratosphere and mesosphere during rocket payload descent. Atmospheric temperature is measured with a wire resistance thermometer or a bead thermistor. That is why using a parachute to reduce the speed of the descent of a rocket payload with measurement instruments is necessary.

The Russian meteorological rocket M-100B with a 60-kg payload used a parachute with a 42 m^2 canopy. This enabled deceleration of the rocket payload falling from a 90-km height to a maximum speed of 400-500 m/s at a 60-km level. Fig. 1 below shows a parachute for M-100B rocket payload on landing.

A new meteorological rocket MERA carries measurement instrumentation of not more than 1 kg and uses a forced-inflation drag-parachute to slow down descent in the mesosphere.

PARACHUTE SYSTEM APPLICATION

A parachute system (PS) is designed to provide proper orientation and deceleration of a weather rocket sonde after its release from a cruise stage at a maximum height of the cruise stage ascent of 100 km, slowing down the recovery sonde descent to less than 300 m/s on its entry into dense atmospheric layers at a 70-80 km height, and maintaining the speed required for rocket sonde instrumentation workability all along the sonde trajectory from as high as 100 km till its landing. At a height below 30 km, the system will enable deceleration of rocket sonde descent to not more than 10 m/s

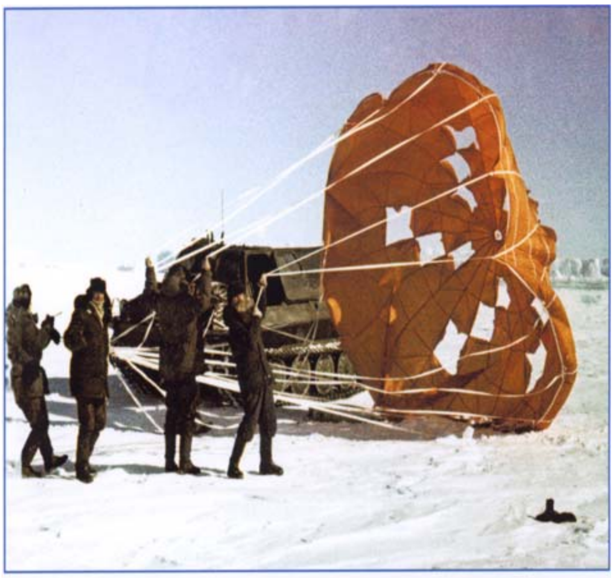

Figure 1. View of parachute for M-100B payload on landing

Wind components are determined from the PS drift through dense atmospheric layers from as high as 70-80 km until landing. The PS is used only once. The weight of a meteorological rocket sonde will be not more than 1.5 kg so that the PS observed given parameters. A horizontal speed at which PS is activated at a 100-km height will be within 100-300 m/s. The PS is operable at any time and in any season, observing rocket sonde motion parameters given:

- a temperature range corresponding to a 0-100-km height interval;
- ground temperatures from +40 to -40°C and relative humidity up to 98%.

Fig.2 shows schematic view of a forced–inflation parachute system

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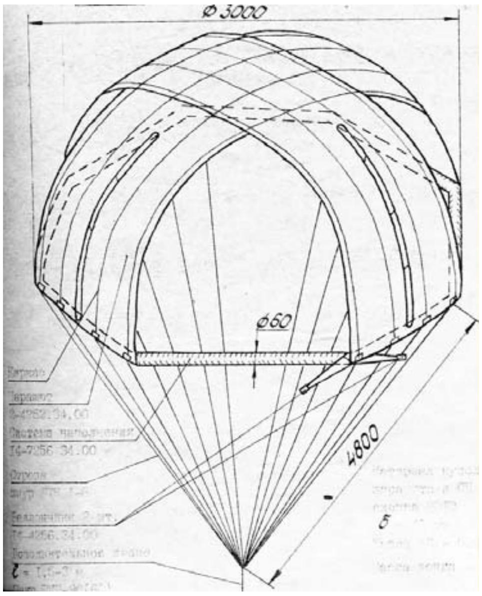


Figure 2 The schematic view of a forced–inflation parachute system

Basic PS technical parameters:

- canopy area 10-12 m^2;
- PS complete weight not more than 500 g;
- PS complete volume not more 0.00085 m^3;
- weight of ethyl acetate per PS 0.01 kg.

PS WORKING PRINCIPLE

Fig. 3 shows a PS operation scheme. A PS is placed inside cruise stage (1) in a special parachute container (4) together with rocket sonde (2) and a pyrotechnic release unit. As the sustainer stage reaches a preset 100-km level, a timer triggers the pyrotechnic unit to release the rocket sonde from the cruise stage together with the parachute container connected with it through release slip (3). Relative release speed will be not less than 10 m/s. As link (5) connecting the sustainer stage with the parachute container is strained, the ball lock is triggered to open drag-parachute (7) compartment (6). The compartment and the rocket sonde acquire relative release speed, and as link (8) connecting the compartment with the parachute container is strained, rocket sonde (2) coupled with a parachute thimble starts pulling out parachute shroud lines (9) sequentially.

Simultaneously, as the parachute container doors open, ethyl acetate bottles start releasing ethyl acetate vapor to PS forced inflation system (10).

As the parachute shroud lines are fully pulled out from compartment (6), the parachute and the rocket sonde get mechanically disconnected from the cruise stage. Within the following 10-15 s, inflation system (10) fully opens the canopy. Aerodynamic forces acting upon the canopy brake and stabilize the ‘parachute and sonde‘ system as it descends through the atmosphere within 35-40 min. till its landing..

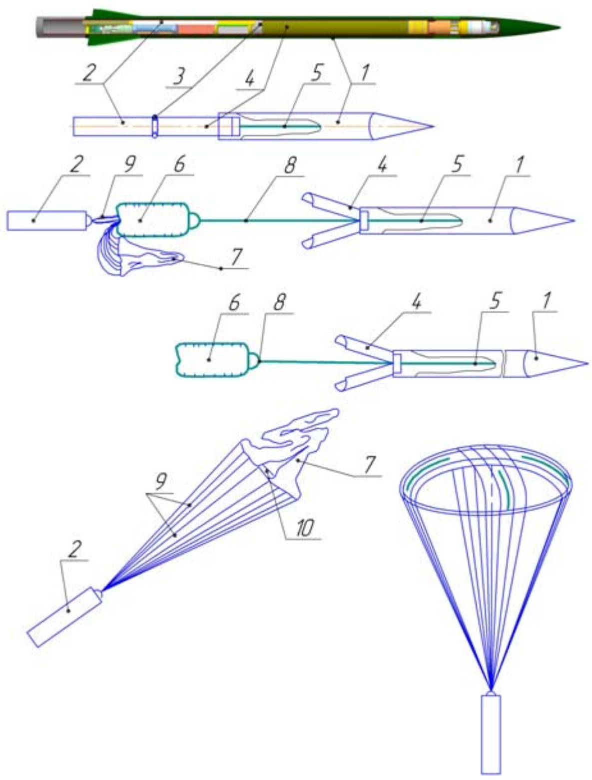


Fig. 3 PS operation scheme .
1 – cruise stage, 2 – rocket sonde, 3 – release slip, 4 – parachute container, 5 – link, 6 – compartment, 7 – parachute, 8 – link, 9 – shroud lines, 10 – inflation system

COMPOSITION,STRUCTURE, AND INTERACTION OF BASIC UNITS

Fig. 4 shows basic parachute units. Parachute canopy (1) is equipped with forced opening system (6) which enables earlier canopy inflation at low atmospheric densities at heights of 100-75 km. The canopy consists of two panels forming an X-shaped structure of 10-12 m^2. The ratio of the canopy blade to its span is 0,26.

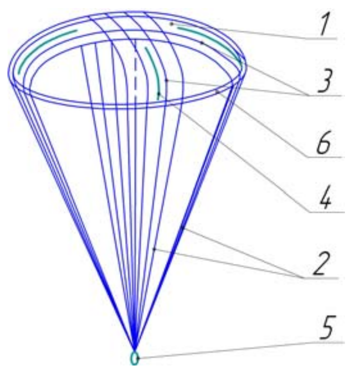


Figure.4. Basic parachute elements
1 – canopy, 2 – shroud lines, 3 – reinforcing cords, 4 - slits, 5 – thimble, 6 – inflation system.

A canopy base is made from 8-12-μ plastic film. A canopy blade is reinforced lengthwise with 8-10 cotton "0" reinforcement cords (3). Each blade has a lengthwise slit (4) in the center to enhance parachute stability during descent. A canopy has 16 shroud lines (2) 4.8-5 meters long, made from Capron cord 'ShTK-1-8', fastened together into a single loose thimble (5).

To the lower blade edges, on the inner canopy side, a forced-inflation system (6) is connected. It enables forced canopy opening at heights of 100-90 km where natural dynamic pressure is too low to open and inflate the canopy. This system allows earlier spatial orientation and soft sonde entry into dense atmospheric layers. Intensive braking of a rocket sonde at heights with low atmospheric density enables the sonde to acquire subsonic speed earlier, which has a considerable effect on measurement accuracy.

Fig. 5 shows the elements of which the system is composed.

The system of forced canopy inflation presents a tore ring (1) of outer diameter 3000 mm with a tore jacket 60 mm in diameter. The tore ring is made from a polymer film 12 μ thick and has two oppositely directed inlet pipes (2) to connect bottles with ethyl acetate. The bottle structure and working principle are described in Fig.6.

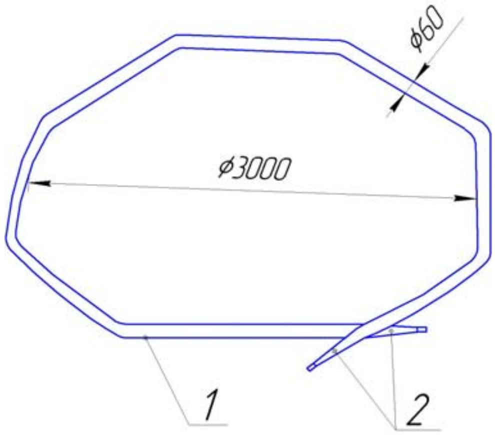


Figure 5. A system of parachute canopy forced inflation
1 – a tore ring, 2 – inlet pipes to connect bottles with ethyl acetate.

A unit of ethyl acetate vapor injection to a canopy inflation system is shown in Fig.6. Bottle (1) contains ethyl acetate (5) and is designed for reliable activation of a canopy forced-inflation system. As a rocket cruise stage reaches upper atmospheric layers with low pressure, pressure difference on the surface of the bottle polyethylene membrane (2) increases. The membrane flexes upward and sets against the rod (3) which is propped by parachute container doors preventing its motion. After the doors open and the container leaves the cruise stage, the rod moves due to pressure difference, and the membrane is punctured by a needle (4). At the ceiling of the cruise rocket stage assent, where atmospheric pressure is practically null, ethyl acetate inside the bottle starts boiling and quickly evaporates. The vapor passes through the hole in the membrane into the forced–inflation system.

After the membrane puncture, it takes 10-15 s to fill the system with ethyl acetate vapor. The system finally acquires a preset tore-ring shape, which results in forced parachute canopy opening.

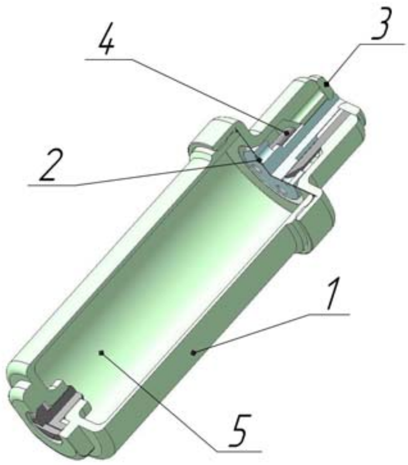


Figure 6. A unit of ethyl acetate vapor injection to a canopy inflation system
1 – a bottle, 2 – a membrane, 3 – a rod, 4 – a puncture element, 5 – ethyl acetate,

A GRAPH OF THE CALCULATED SPEED OF PS DESCENT WITH ROCKET SONDE

Figure 7 presents a graph of the calculated speed of descent of the parachute system. Curve (1) shows the vertical distribution of the speed of a 1.2-kg rocket sonde descending on a parachute with a 10-m^2 canopy. Curve (2) corresponding to the free fall of a body without a parachute is given for comparison. It can be seen that a forced-inflation PS starts braking and decelerating of the rocket sonde at 95-90 km, thus letting it pass the sonic barrier at 74-72 km.. At 70 km, the rocket sonde speed is not more than 200 m/s, which satisfies the requirements for temperature measurements with airborne sensors.

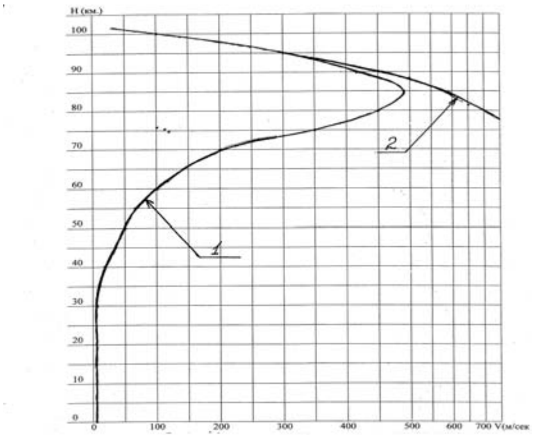


Figure 7. Calculated speed of PS descent

1 – a graph of the speed of PS descent with a 1.2-kg payload; 2 – a graph of the free fall of a 1.2-kg body

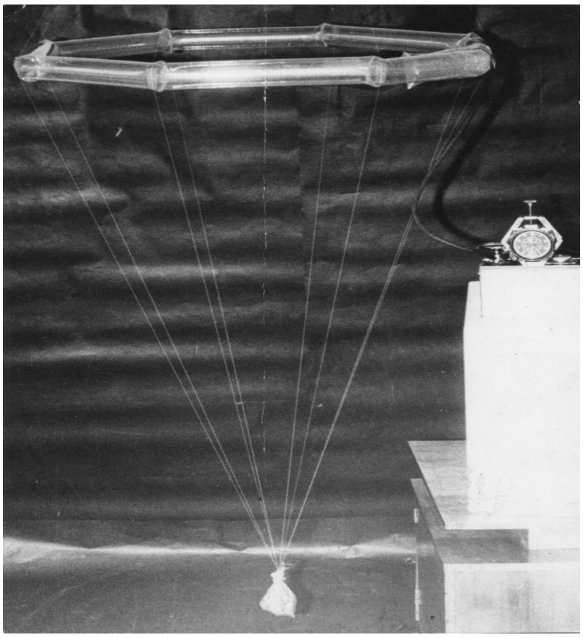


Fig.8. An episode of testing the forced-inflation parachute system.

An example of tracking rocket head descent on a forced-inflation parachute for two rocket flights is shown in Fig. 9 The weight of the recovery instrumentation module is not more than 1 kg.

The Fig. 9 shows the preset direction (straight line) of two close rocket launchings. The green dot indicates the stating point of forced parachute inflation for given launchings. The dashed line shows rocket sonde trajectory projection on the earth's plane. The departure of this curve from the preset launching direction is caused by the wind. In Fig 9 "0" means the inflation and opening the PS. The parachute system with a 10 m^2 canopy and a 0,8 kg scientific payload sustains specific loading of 0,14 kg/m^2, thus enabling measurements of horizontal wind components based on trajectory tracking from a 80-km height. The typical example of wind measurements by the parachute drift is shown in Fig.10

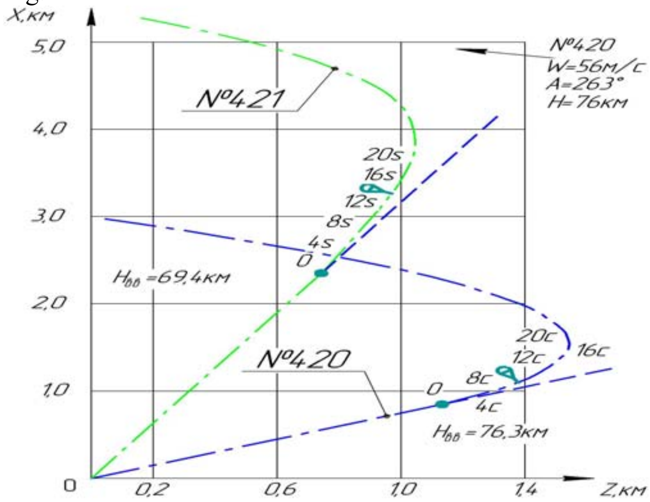
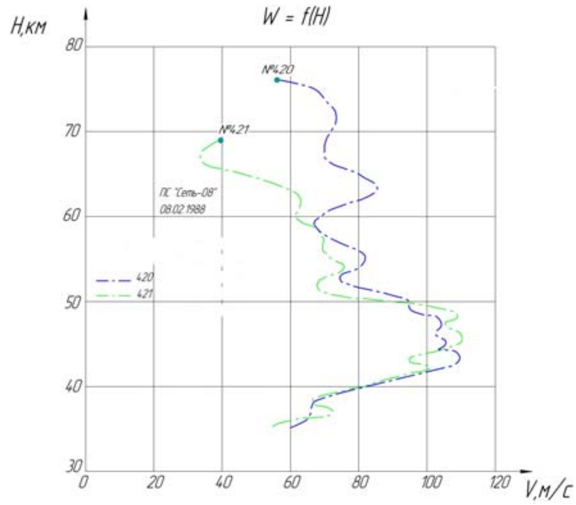


Figure. 9. See explanation in the text

Figure 10. the example of wind characteristics measured



by the parachute drift.

CONCLUSIONS

1. A parachute with forced inflation and opening provides stabilized descent of scientific instruments from an altitude of 90-100 km , a maximum speed of about 500 m/s at 80 km and the resulting rapid braking in the mesosphere.
2. The proposed parachute system operation is reliable at a minimal pressure head of about 0.03…0.4 Pa.
3. The parachute system with a 10 m^2 canopy and a 0,8 kg scientific payload sustains specific loading of 0,14 kg/m^2, thus enabling measurements of horizontal wind components based on trajectory tracking from a 80-km height.