# PK Vozdukh airships

Peter Lobner, 11 February 2022

## 1. Introduction

The production cooperative PK Vozdukh, located in Moscow, Russia, developed a number of airship designs, including a multi-purpose, helicopter / airship hybrid and an all-metal, variable volume airship. These are particularly noteworthy because they incorporate novel operational or design features, which are described in this article.

## 2. Multi-purpose, helicopter / airship hybrid

The Vozdukh multi-purpose, helicopter / airship hybrid was a design concept for a semi-rigid helistat-type airship with a payload of 10 metric tons (11 tons). It was intended for regional passenger and cargo service and agricultural applications.

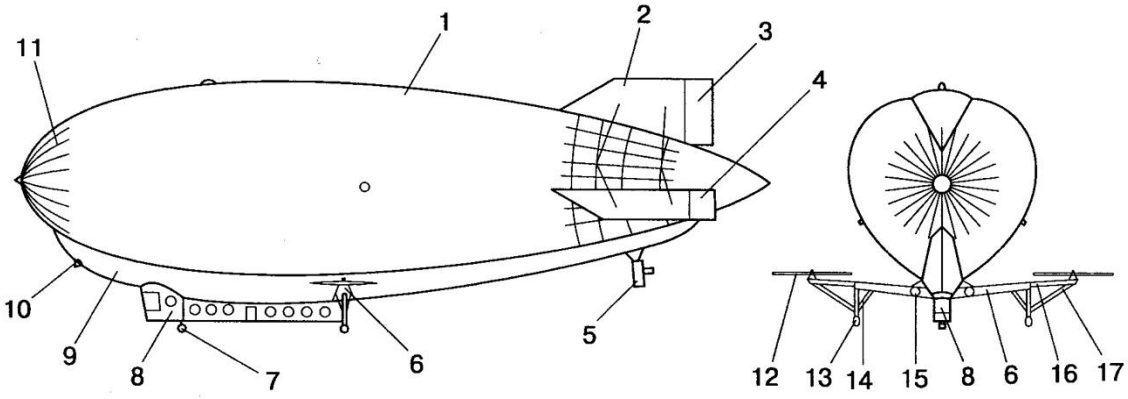
This hybrid vehicle used combinations of aerostatic, dynamic and aerodynamic lift in various flight regimes. The available aerostatic lift was less than the empty weight of the vehicle, so it was heavier-than-air on the ground with no payload. During takeoff and landing, the dynamic lift from the helicopter part of the hybrid vehicle carried the entire weight of the payload plus a small fraction of the empty weight of the vehicle. The helicopter part consisted of two powerful rotors supported amidships on a transverse, cantilevered, aerodynamic beam that also functioned as a wing. During forward flight, the vehicle would fly with a positive angle of attack, with the wing and the gas envelope generating aerodynamic lift and taking some of the load off the rotors.

The wings had a fiberglass skin on the inner section, which had an angle of incidence of 6-8° to help generate aerodynamic lift during forward flight. The wing outer section was an open truss structure under the rotors. This reduced the interference between the wing structure and the airflow from the rotors. The engines for the rotors were installed near the wing roots and drove the rotors via a clutch, transmission, and driveshaft that ran inside the wing. Cross-shafting

between the engines enabled one engine to drive both rotors (i.e., after the failure of one engine).

An important advantage of this hybrid design is that no exchange of ballast is needed when picking up or delivering a payload. The empty vehicle is heavier-than-air and is stable on the ground throughout a load exchange.

The passenger version was designed to carry 50 people at speeds of up to 120 kph (74.6 mph) over a distance up to 1,000 km (621 miles). The hybrid vehicle would fly at low altitudes (typically < 300 m / 984 ft) that did not interfere with other civil aircraft routes. An economic analysis of such routes among destinations near Moscow showed that a multi-purpose, helicopter / airship hybrid could complete its route in 1/2 to 1/3 the time and in more comfortable conditions that buses, but at twice the price of a comparable bus ticket.




*Legend:*
*1 – non-rigid gas envelope; 2 – three stabilizer fins in an inverted-Y configuration, 120º apart; 3 – rudder; 4 – ruddervator (combined rudder / elevator); 5 – cruise propulsion engine ; 6 – cantilevered, transverse aerodynamic outriggers are attached to the keel; 7 – nose landing gear; 8 – gondola; 9 – rigid metal keel, 10 – mooring / anchoring fitting; 11 - bow reinforcement; 12 – prop / rotors; 13 – main landing gear attached to outriggers; 14 – main landing gear brace; 15 – engines for prop / rotors; 16 – synchronizing shaft connects the prop / rotors & distributes power to both in the event of one engine failure; 17 – diagonal strut supports engine*

*General arrangement of the PK Vozdukh multi-purpose, helicopter / airship hybrid. Source: Boyko (2021)*

## General characteristics of the multi-purpose helicopter / airship hybrid

| Parameter | Multi-purpose airship |
|---|---|
| Airship type | Semi-rigid, semi-buoyant helicopter / airship hybrid |
| Length | 60 m (196.9 ft) |
| Diameter, max | 15 m (49.2 ft) |
| Lift gas | Helium |
| Envelope gross volume | 7,000 $m^3$ (247,203 $ft^3$) |
| Envelope type | Multi-layer fabric |
| Aerostatic lift | About 7,200 kg (15,873 lb) |
| Weight, empty | > aerostatic lift |
| Payload | 10,000 kg / 10 metric tons (22,046 lb) |
| Accommodations | Crew of 3 (pilot, co-pilot & engineer) and up to 50 passengers |
| Propulsion and dynamic lift system | • 1 x propulsion engine rated @ 600 kW (804 shp) driving a shrouded propeller installed under the tail, and capable of vectoring thrust 90º left / right and 20º up/down in low-speed flight & hover<br>• 2 x engines rated @ 1,500 kW (2,012 shp) each, driving fixed 8 m (26.2 ft) diameter rotors with typical helicopter controls<br>• After reaching a prescribed altitude, this hybrid airship is designed for auto-rotation flight |
| Speed, max | 120 kph (74.6 mph) |
| Speed, cruise | 110 kph (68.4 mph) |
| Operating altitude | 300 m (984 ft) |
| Range | 1,000 km (621 miles) |

The flight of a multi-purpose, helicopter / airship hybrid is carried out as follows:

- **At takeoff**: All of the engines are operating and the rotors generate the dynamic lift needed for a vertical takeoff at maximum weight. The propulsion engine drives the airship forward and makes the transition to forward flight with a positive angle of incidence (up angle). As aerodynamic lift increases with airspeed, the power to the rotors can be reduced.

- **At cruise altitude:** The propulsion engine drives the airship forward at a prescribed speed while the rotors are disengaged from their drive engines and set to autorotate in the “free”

airflow, from which energy is extracted to overcome blade drag and continue to turn the rotor. During steady-state auto-rotation at a constant altitude, the propulsion engine has to operate at a higher power setting than it would if the rotors were powered. The “free” airflow isn’t really “free,” and the propulsion engine has to balance the added drag from the auto-rotating rotors.

The hybrid airship can remain in a steady-state cruise at constant altitude in this configuration with the rotor engines turned OFF to improve fuel economy. Author Michael Boyko (2001) described this flight mode as follows: “The flight mass of the airship is balanced by the aerostatic lifting force of a gas lighter than air filling the airship envelope, the aerodynamic lifting force of the airship body flying under a positive attack plane, the aerodynamic lifting force of the wing and the dynamic lifting force (thrust) of the autorotating rotors.”

- **For landing:** At a destination, the engines for the rotors are restarted and the rotors are reengaged with their drives, providing powered dynamic lift. The airship’s total weight is less than at takeoff due to fuel consumption in flight. The airship may approach the landing site on a diagonal or vertical flight path and execute a vertical landing.

The hybrid airship typically would be moored or anchored when parked using a fitting under the nose. In a strong wind, the airship move on its tricycle landing gear and weathercock around its mooring / anchor point as the wind changes direction.

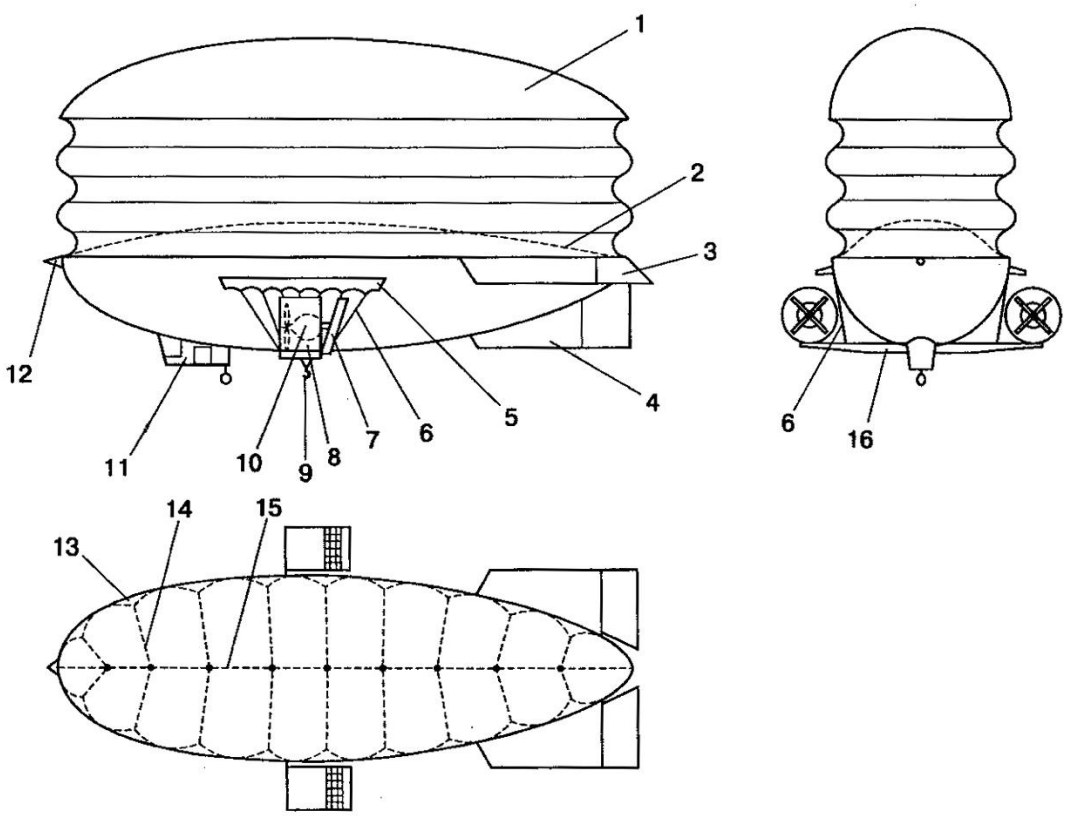
### 3. All-metal, variable volume airship

PK Vozdukh developed a design concept for an all-metal, variable volume airship intended for transporting suspended cargo and installing some large items from a hover above a remote site.

The airship’s metal gas envelope (or shell) is made of welded titanium alloy 0.1 mm thick, with corrugations in the horizontal plane, which allow the shell to expand and contract like an accordion when the ambient temperature changes or when the flight altitude changes. Helium or hydrogen lift gas can be used, since the all-metal hull

eliminates most sources of static electricity (i.e., from fabric and plastic hull material).

The minimum volume of a compressed shell is 4,000 $m^3$ (141,259 $ft^3$), and the maximum volume of a fully expanded shell is 6,750 $m^3$ (238,374 $ft^3$). Such an increase in volume results in an increase in the shell height by 10 meters (32.8 feet) as the “accordion” section fully expands.




*Legend:*
*1 - shell; 2 - air balloon (ballonet); 3 - horizontal tail & elevators; 4 - vertical tail & rudder; 5 - external catenary belt; 6 - wing suspension cable; 7 – thrust deflector in propeller slipstream; 8 – propeller shroud; 9 – extendable cargo lifting device; 10 — ASh-82 piston engine; 11 — cockpit; 12 — docking fitting; 13 - inner catenary belt; 14 - springy rope; 15 - axial cable; 16 – wing*

*General arrangement of the Vozdukh all-metal, variable volume cargo airship. Source: Boyko (2021)*

## General characteristics of the all-metal, variable volume airship

| Parameter | All-metal, variable volume airship |
|---|---|
| Airship type | Rigid, all-metal airship |
| Length | About 42.7 m (140.1 ft) |
| Width, overall | About 24.5 m (80.4 ft) |
| Height, compressed | About 12.7 m (41.7 ft) |
| Height, expanded | About 22.7 m / 10 m more than compressed (74.5 ft) |
| Lift gas | Helium or hydrogen |
| Envelope volume, compressed | 4,000 $m^3$ (141,259 $ft^3$) |
| Envelope volume, expanded | 6,750 $m^3$ (238,374 $ft^3$) |
| Envelope type | All-metal, welded titanium alloy, 0.1 mm thick |
| Aerostatic lift | About 7,000 kg (15,432 lb) |
| Dynamic lift | 4,000 kg / 2,000 kg per engine (8,818 lb total) |
| Weight, expandable envelope | 1,500 kg (3,307 lb) |
| Weight, propulsion system | 3,000 kg (6,614 lb) |
| Weight, fuel | 1,000 kg (2,205 lb) |
| Payload | 5,000 kg (11,023 lb) |
| Propulsion and dynamic lift system | 2 x ASh-82 piston engines rated @ 750 kW (1,006 shp) each, driving 4 m (13.1 ft) diameter shrouded propellers, with thrust deflectors in the slipstream to provide up / down thrust vectoring |
| Speed, cruise | Up to 100 kph (62.1 mph) |
| Range | 1,800 km (1,118 miles) @ 50 kph (31 mph), 36 hour flight<br>500 km (311 miles) @ 100 kph (62.1 mph), 5 hour flight |

Adequate rigidity of the metal shell during volume changes is maintained by a flexible array of internal cables:

- An axial cable (15) connects the bow and stern of the shell.
- A “inner” catenary belt (13) is installed along the inner wall of the shell, along the central part of the corrugated section.
- Spring cables (“springy rope,” 14) connect the inner catenary belt (13) to the axial cable (15) and maintain tension on the outer walls of the “accordion.”

The air ballonet in the lower part of the shell is used to maintain the desired pressure of the lift gas, and it can be used for ballasting the airship in some cases.

A wing is attached amidships, at the bottom of the airship shell. Each wing supports a shrouded propeller that is directly driven by an ASh-82 piston engine. Thrust deflectors in the propeller slipstream provide up / down thrust vectoring to improve the maneuverability of the airship, particularly during low speed and vertical flight.

The thrust deflectors also enable the airship to fly significantly heavy or light and execute a load exchanges with little or no ballast exchange. For example, the airship with cargo can arrive “heavy” with the thrust deflectors pointed down, providing dynamic lift and enabling a vertical landing. On the ground, the thrust deflectors can be pointed up and the cargo safely removed from an otherwise “light” airship. After the load is removed, the “light” airship, with the deflectors still in the up position, can make a vertical takeoff and safely fly to its next destination. Alternatively, the airship could receive some ballast to establish its normal buoyancy condition when empty.

The airship is equipped with a lifting device that can be lowered to pick up or deliver cargo while hovering.

The weight of the wings and engines is supported by external catenary belts and support cables (5 & 6) that distribute this load more broadly into the metal hull.

Tail fins (3 & 4) with control surfaces provide stability and control during forward flight.

A docking device (12) is installed in the bow of the airship hull, which allows it to be attached to a mooring mast. While moored, the airship can weathercock into the prevailing wing by pivoting on the landing gear wheel under the cockpit.

Accessways for inspection and maintenance are available to the wing and engines and the air ballonet.

## 4. For more information


- Yu.S. Boyko, “Aeronautics: Tethered, Free, Managed,” pp. 385 – 388 (in Russian), ISBN 5.8122-0233-8, Publishing house MGUP, Moscow, Russia, 2001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