L. KONSTANTINOV

BASIC PRINCIPLES OF HEAT AIRSHIP OPERATION AND DESIGN.

Part 2 The Theory of Heat Airship

Under the term "Heat Airship" a controlled aerostatical flying vehicle supplied with the propulsive device the and lift of which creates by heated gas, is meant.
As a lifting gas, various kinds of gas may be studied, that is: air, water steam, end product of fuel combustion, and even such light gases as hydrogen, helium, ammonia and others.
Two brothers Etienne and Josef Montgolfier have proposed and realized the idea how to use the heated air ("smoke") in 1783 yet. And it should be noted herewith that when searching for the optimum "smoke" the brothers have tested combustible products of various kinds of inflammable materials: wood, paper, straw, wool, provoking so the mocking of not their contemporaries, but also of some critics in our times. It was not at all nonsense when they have chosen the final version of burning the wet straw, how it could be shown on the face of it, as the mixture of the heated air with water steam possesses the elevated lift in comparison with the pure heated air. They even had no any notion of the thermodynamical and thermophysical properties of the different gases, but they came to a very correct and principal result, as gases with a higher gas constant value provide greater lift (formulas 1.1-1.3). In this connection it would be noted that combustion products of the hydrocarbon fuels, containing water steam, also possess much greater lift than the pure air only.
Peculiarities in obtaining the steams of various liquids (water, ammonia, etc.) and their behavior under the different temperatures can define the possibility of their application taking into account their operational and economical factors. If not to analyze in details all the possibilities in usage of different heated gases (steams), we can underline yet that the most rational substances for heat airships shall be: air, combustion products of different kinds of fuels and light lifting gases (hydrogen and helium are for the special versions to be studied below).
Taking into account that combustion products generated by the aircraft engines and more over mixtures of the air with the products of combustion do not much differ from the heated air as to their thermophysical properties, later on we'll study an elementary heated air only as a lifting gas to analyze the heat airships with the heated by combustion products air. The temperature of heated air shall significantly influence upon specific buoyancy and the maximum permissible temperature. The last depends upon vehicles design peculiarities, upon the materials being used as well as upon the method of the air heating. For the moment, we may admit the value of 600°C as maximum permissible value of the heated air temperature for heat airships designs. As to the characteristics of heated air specific buoyancy under the various temperatures and the flight altitudes - see table 6.

Table 6

Specific buoyancy of the heated air, Δρ kg/m³

Air temp. tair, °C / *Altitude H, m*	100	200	300	400	500	600
0	0,27997	0,47937	0,60977	0,70114	0,76908	0,82129
500	0,27621	0,46488	0,58099	0,73613	0,73278	0,78681
1000	0,27281	0,45026	0,55331	0,64695	0,69783	0,75352
1500	0,26884	0,43577	0,52661	0,62082	0,66418	0,72108
2000	0,26454	0,42148	0,50093	0,59544	0,63181	0,68969
2500	0,25987	0,40731	0,47623	0,57072	0,60065	0,65926
3000	0,25482	0,39321	0,45245	0,54661	0,57066	0,62973
3500	0,24945	0,37926	0,42959	0,52315	0,54182	0,60111
4000	0,24386	0,36553	0,40763	0,50039	0,51413	0,57345
4500	0,23801	0,35194	0,38654	0,47823	0,48752	0,54666
5000	0,23195	0,33856	0,36629	0,45674	0,46199	0,52077

As we can see from the Table 6, the application of heated up to the t = 600 °C air may create specific buoyancy *Δρ* making up 0.7...0.8 off the value *Δρ* of helium and hydrogen. In contrast to the air, light gases (hydrogen, helium), when being heated, slightly increase their specific buoyancy *Δρ*. For example, if to heat hydrogen from 50 °C to 400 °C, the value *Δρ* becomes higher by 3 % approximately (see Table 7), but the gas density shall decrease herewith in inversely proportional manner to the absolute temperature (formula 1.2), that is more than twice. Effect of the gas expansion during their heating may be used in the special design heat airships.

Table 7

Specific buoyancy and density of hydrogen and helium, kg/m³
at the different temperatures. Altitude H = O, outside air temperature tair = 15 °C

	t, °C	50	100	200	300	400
hydrogen	Δρ	1,15022	1,16032	1,17412	1,18311	1,18942
	ρ	0,07541	0,06531	0,05149	0,04251	0,03621
helium	Δρ	1,07482	1,09502	1,12262	1,14059	1,15323
	ρ	0,15081	0,13061	0,10301	0,08503	0,07241

In essence, the heat airships may be subdivided into following types:

1) with no thermal insulation of the skin (particular case: heat balloon - Montgolfier, fig. 17a).

2) with thermal insulation of the skin (fig. 17b).

3) combined or compromise type with warming of light lifting gas (helium, hydrogen - see fig. 17c).

In the same way as the gas-filled airships, heat airships may have the rigid, non-rigid and semi-rigid structures. And every type of them may have varieties stipulated by their different peculiarities in their designs.

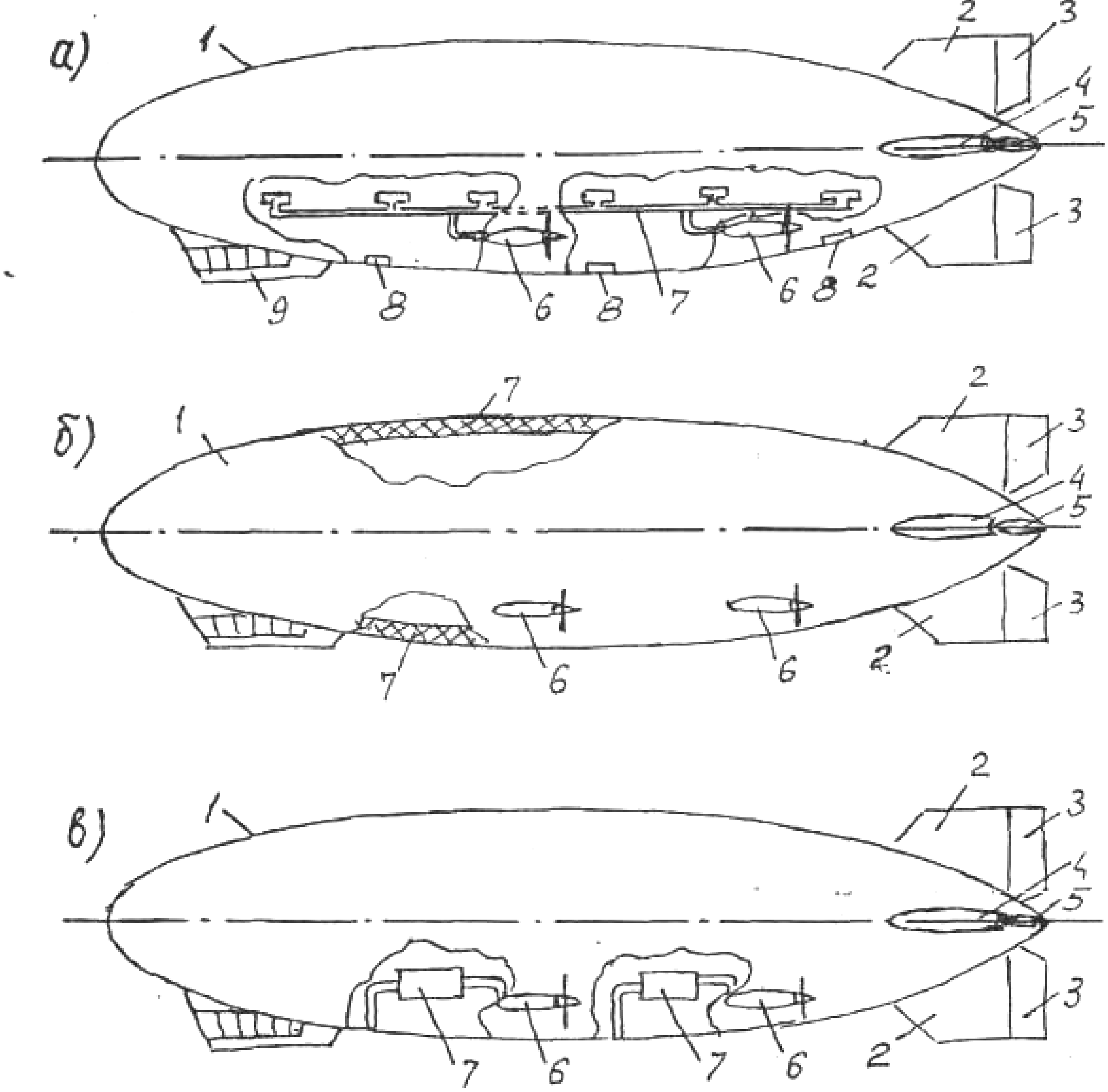

Fig. 17. Different systems of heat airships:

a) *without any thermal insulation of the skin*

1 *- supply and distribution of exhaust gas*

2 *- exhaust air valves*

3 *- thermal insulation*

4 *- heat exchanger inside gas holder*

b) *with thermal insulation of the skin*

c) *of the combined design*

The heat airship with non-insulated skin has the increased heat transmission to environment. To keep the flying vehicle "afloat", it requires the big fuel consumption, so we cannot consider such airships as the high efficient transport facilities. Their application shall be limited by shot range flights. Heat airships with thermically insulated skin can keep themselves in the air due to diminished thermal heat losses of utilized exhaust gases heat. So their performances will improved sufficiently in comparison with non-insulated skin heat airships.

There are such advantages of the heat airships in comparison with the gas-filled ones:

- giving helium or hydrogen up as a very expensive and explosive lifting gases;
- higher simplicity of design and not so high requirements to the envelope tightness; as result, simplified production process and reduced the capital investments costs for the airship making;
- more simple control and piloting in particular under the vertical maneuvering, thus utilization of ballast or lifting gas losses shall be excluded in the case;
- reduced aircrew (as in the airplane);
- the ground maintenance simplifies.

Disadvantages and difficulties in the airships making will be discussed later on.

The heat airship of the so called combined version (figure 17b) represents itself unfulfilled airship of the classic type, the heating of the light lifting gas shall be provided by any heat source through the heat exchanger into the gas holder. In many cases such airships call as “thermoplane”, but somewhat it is not so correct, because the word "plane" (that means "wing" or "aerofoil") characterizes the flying vehicles with the dynamic principle lift creation (airplane, hydroplane, aerospacecraft, etc.).

Degree of lifting gas volume fulfilment is determined by equilibrium of airship weight and the gas lift near the ground level. The additional lift may be created by means of lifting gas heating and thus due to gas expansion and its volume increasing. Moreover, the increase in temperature of lifting gas somewhat rises the specific buoyancy, and due to the fact all airships performances improve. The airships of the above version have both advantages and disadvantages, and these properties may characterize both gas-filled and so-called “pure” versions of the heat airships, where lift creates by heated air.

(To be continue)