DEVELOPMENT, TRYOUT AND MANUFACTURE OF THE HEAT PIPES FOR THE COMMUNICATION, NAVIGATION AND GEODESIC SATELLITES

N. A Testoedov, V. V Dvirniy

Abstract

In the report is reviewed the issue of design, on – ground experimental tryout and manufacture of the heat pipes of the spacecrafts, produced by NPO PM in honor of academician M. F. Reshetnev.

The part of Russian spacecrafts in the world group reaches 12 % (Fig. 1) and 70 % of this number are produced in NPOPM in honor of academician M. F. Reshetnev (further NPOPM). Thus, communication, navigation, geodesic satellites of NPO PM form about 8% of all in orbit spacecrafts in the world (Fig. 2).

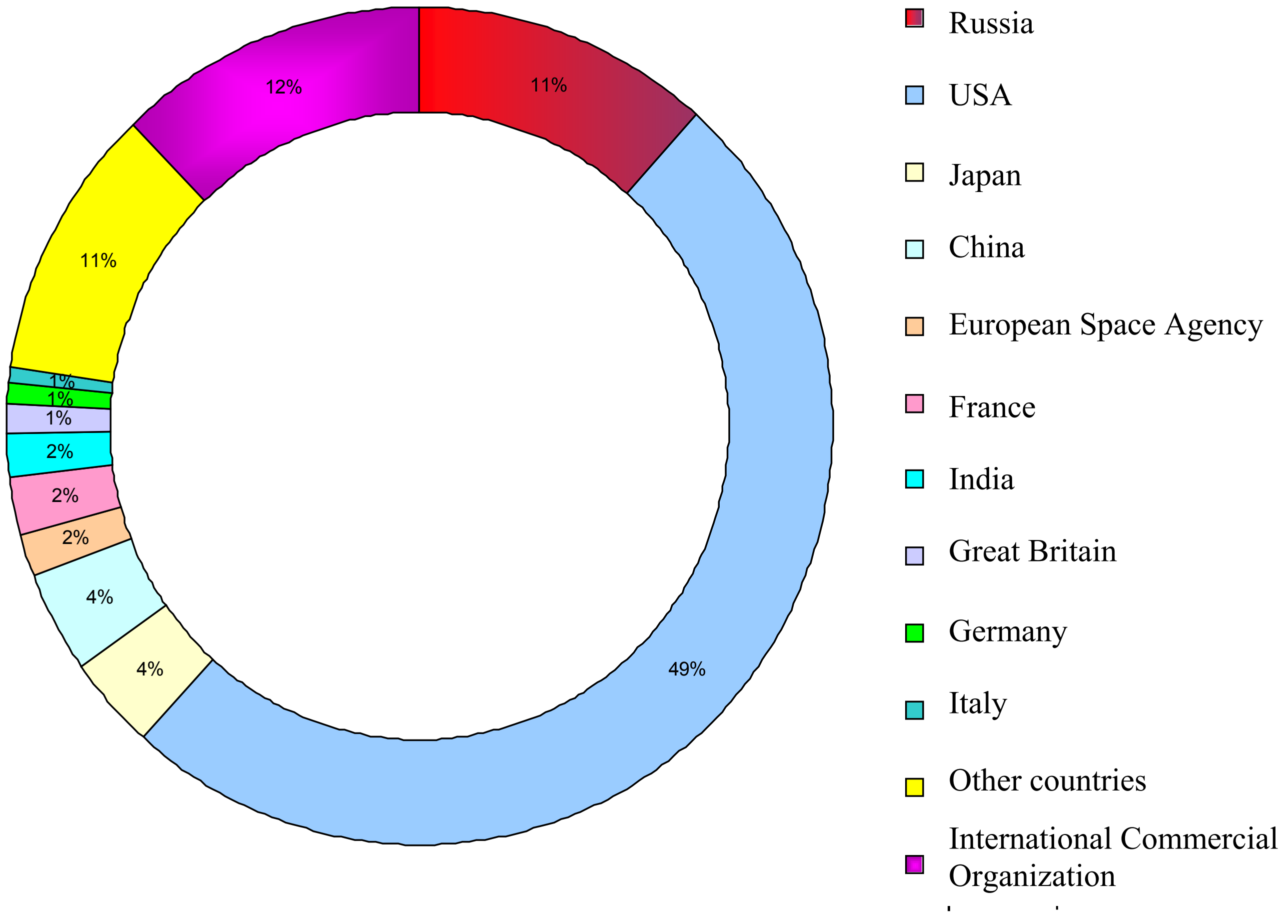
At NPO PM are developed, the first in the branch, ammoniac unregulated heat pipes for the "Gorizont" type satellites and the first in the country, gas – regulated heat pipes for the "Luch" type and "Smallsat" type sattelites.

Later on the heat pipes were adopted practically in all spacecrafts of NPO PM production, and designs of future – technology satellites in the containerness variant are based on the usage of light honeycombs with aluminum heat pipes. There were developed the structures and the technology of high – precision profiles production, the technologies of refueling purification, the control, express – control, tests and the ensuring of no – failure, continuous heat pipes operation during 10 years and more.

The main characteristics of the first heat pipes of NPO PM are presented in the materials of the IX international conference (USA, 1995) [1]. The structures of many unregulated and gas - the certificate of the authorship defends regulated heat pipes. The first heat pipe, developed at NPO PM in 1976, is represented in the Fig. 3. The cross sections of heat pipes made of pressed aluminum profile are performed on the basis of requirements, made to the main characteristics in the specific spacecrafts.

Thanks to the size high precision of the profile grooves, the heat pipes, developed in the NPO PM in honor of academician M. F. Reshetnev compete with the heat pipes of NASA USA made of «Microextrusious Minelex» profile in heat – transfer properties and resources. Gas regulated heat pipes confirmed their characteristics at the nominal operation being installed in the space satellite «Luch» type and surpass the analogous heat pipes, manufactured for the French spacecrafts, thanks to the patent design of the turbulence promoters and profiled rods in the condensation zone.

The ground try out was conducted and for the first time in the world, was tested the loop heat pipe, installed in three "Gorizont" satellites with the confirmation of the efficiency in the orbit conditions (Fig. 4). High thermo-technical characteristics of the developed heat pipes are received and confirmed as a result of experimental researches, ground and flying tryout, and also at the reliable operation in more that seven space systems.



Over 40 types of spacecraft have been designed in NPOPM since its foundation. The total number of orbited spacecraft is over 1130.

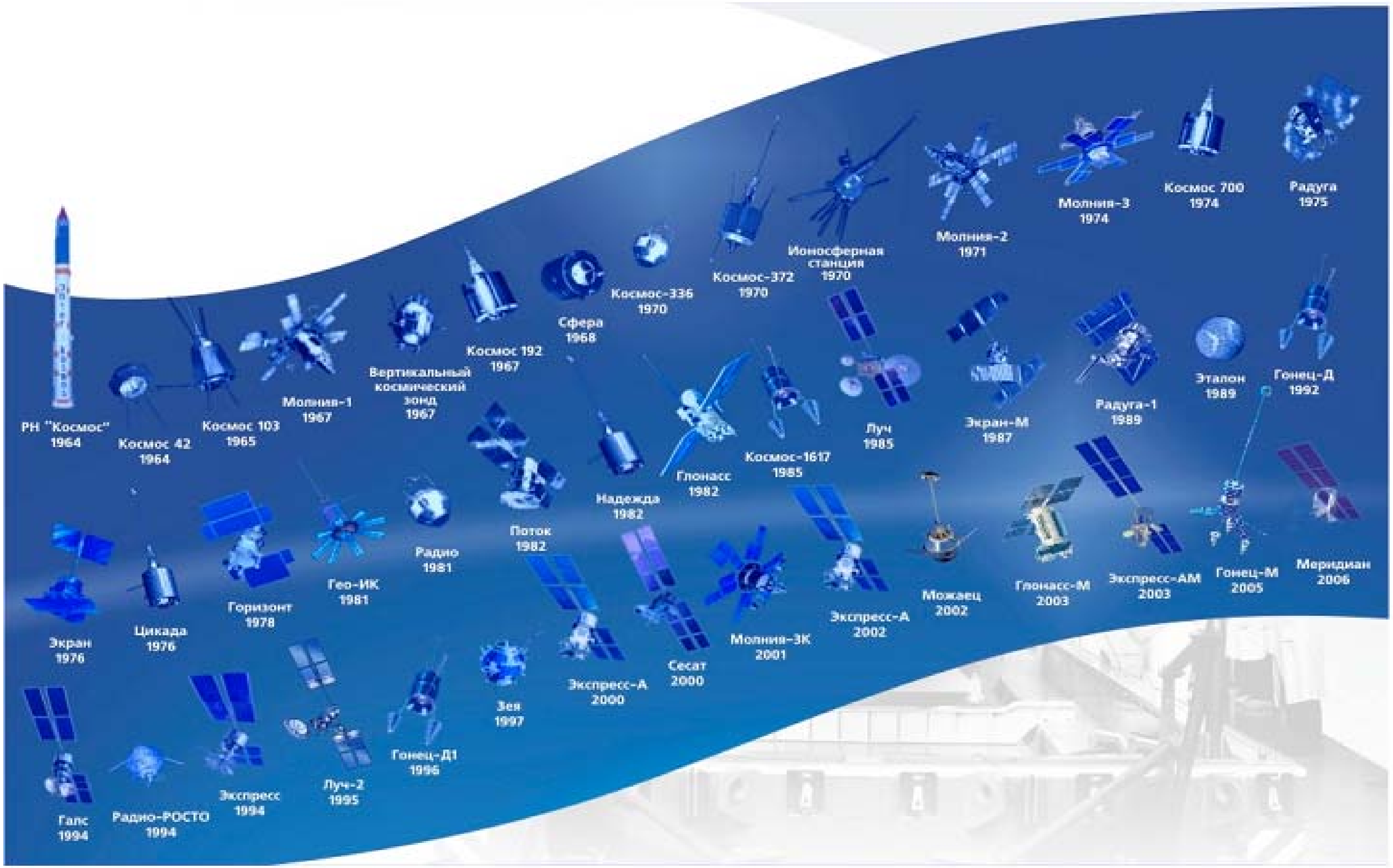


Fig. 2. The main types of spacecraft

The heat pipes for heat transfer from attitude control system devices to the thermal liquid of the thermal control system.

Specification

Output heat power at the vaporizer temperatures not over 35 °C, condenser temperature not over 26 °C and at the thermal liquid consumption 90 cm^3/s, W, not less	18
Temperature drop between vaporizer and condenser, °C, not more	9
Operation life, years	5
Warranty period,	10
Mass, kg, not more	0,5

Fig. 3. The first heat pipe of NPO PM

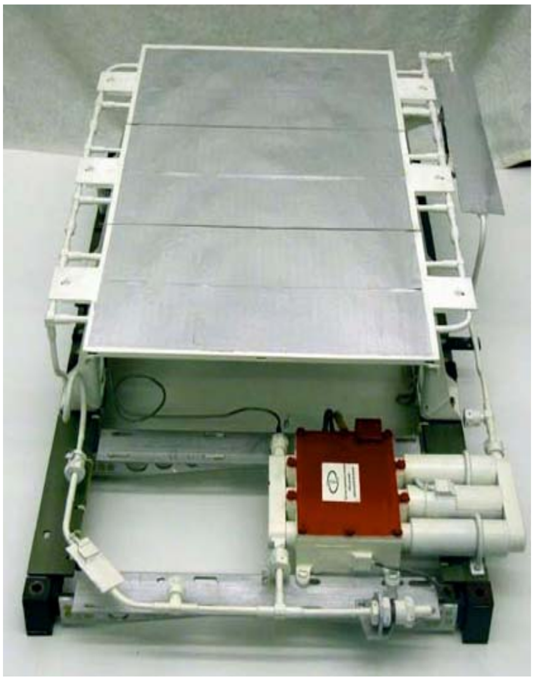


Fig. 4. Loop heat pipe installed in “Gorizont” spacecraft flight module

At present NPO PM accepted the conception of the spacecraft construction in nonsealed execution.

This conception will be followed on the example of “Glonass” system development (Fig. 5).

Starting from “Glonass K” the temperature control system is built on thermal pipes. Their number on such type of spacecrafts of NPO PM production is about eighty of different length and different configurations (Fig.6).

To provide the spacecraft thermal conditions during the long term of life time it was designed and manufactured the special precision profile for thermal pipes.

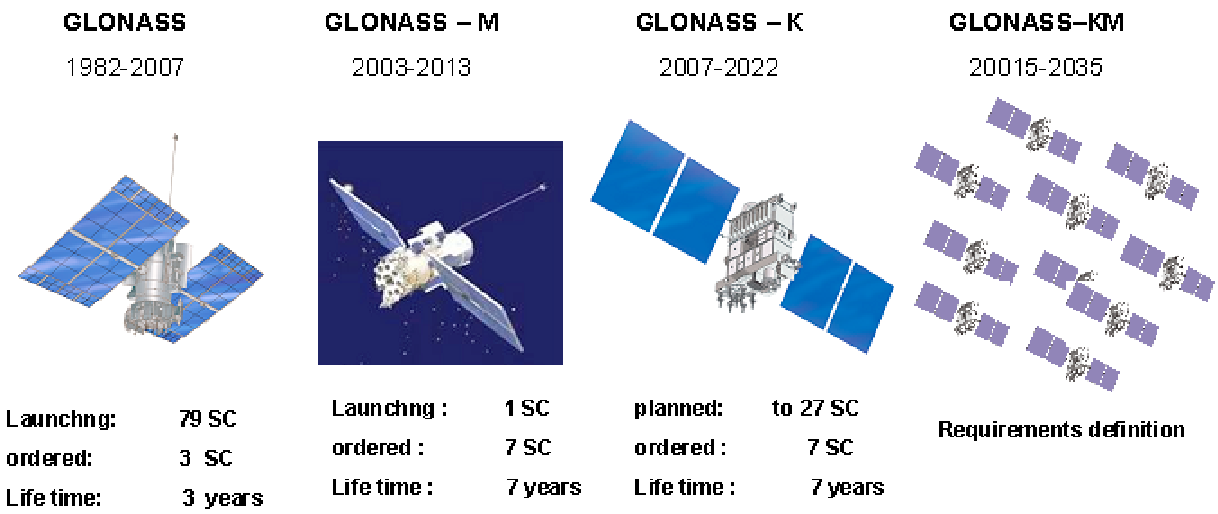


Fig. 5. Conception of “Glonass” system development

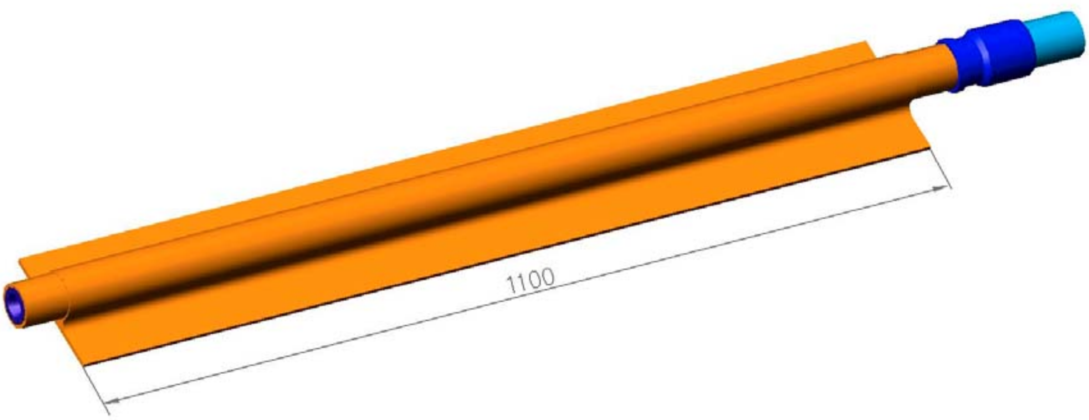


Fig. 6. Heat pipe made of light – weight aluminum shape with Glonass structural wick

Function

The heat pipe is intended for the heat rejection from devices to the radiant surfaces and for the temperature field smoothing on these surfaces.

Specification

Heat power transmission at the temperature difference between vaporizer and condenser not more than 5°C, Wt, not less	35
Life time, years	10
Mass, kg, not more	0,3

NPO PM method of profiles optimization.

To research the effectiveness of the thermal pipes on two criteria – weight and heat transfer property was reviewed the dependence

$k = k(D)$ (Fig. 7), where D is external diameter of the cylindrical part of the thermal pipe profile and k is defined as

$$K = QL(l_1 F\rho),$$

where l_1 is thermal pipe actual length of 1 m effective length taking into account the pressurization on the end faces, m.

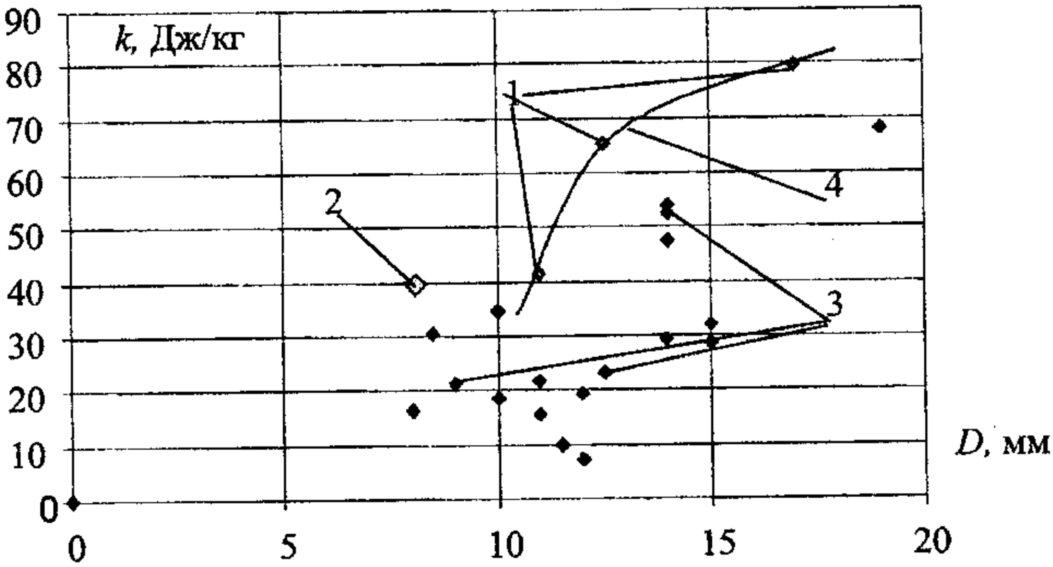


Fig. 7. Dependence of the thermal pipes specific heat transfer capability from the external diameter: *1* – are profiles with axial grooves of the bulb form; *2* – are profiles with the axial grooves of trapezoidal form; *3* – are all the other types of profiles; *4* – is assumed dependence of k from D for the profiles with axial grooves of the bulb form

Shown method allows to choose the thermal pipes profiles, which at a given heat load have the least weight.

To estimate the conformity of the heat pipes profiles to the used operating environment and to the operating temperature range is formed the general performance criterion:

$$Vr = f(\delta w_{min}/L),$$

where

$$\frac{\delta w}{L} = A \frac{\mu_0^{1/2} r_c^{1/4}}{p^{1/4} L^{1/2} \sigma^{1/2}} \cdot \frac{w_{\min}}{\sqrt{\dfrac{F w_{\min}}{p^3}}},$$

where δ – is a thickness of the boundary layer; L is a heat pipe effective length, A is coefficient, dependent on the temperature, in the conditions of assigned task it can be considered as constant, ρ is a density of the liquid phase of the working substance, μ_0 is dynamic viscosity, w_{min} is minimal width of profile groove, p is perimeter of the profile grooves.

Obtained criterion of the heat pipe profile effectiveness is generated from the physical property of the working fluid and geometric characteristics of heat pipes profile. As initial suppositions are accepted the following:

- the value drop of the heat power output is caused by friction loss in the axial grooves, at that the flow in the grooves is a merged boundary layer;
- typical flow velocity in the grooves is caused by the action of the capillary forces;
- thickness of the boundary layer is connected with heat pipes effective length by the following relation

$$\frac{\delta}{L} = A \frac{1}{\sqrt{\frac{\rho u L}{\mu_0}}},$$

where δ is thickness of the boundary layer; L is heat pipe effective length, A is coefficient, dependent on the temperature, in the condition of the assigned task can be considered as a constant, ρ is a density of the liquid phase of the working substance, u is characteristic velocity of the liquid phase in the capillary structure, μ_0 is dynamic viscosity;

- minimal width of the groove w_{min} is proportional to the thickness of the interface;
- stacking velocity of the working substance movement on the grooves is calculated from the Q value for L = 1 m at the known r, that is the value of the latent heat of the liquid phase vaporization - ammonia.

The dependence with the reference to the test results of 25 different heat pipes profiles is shown on the fig.8.

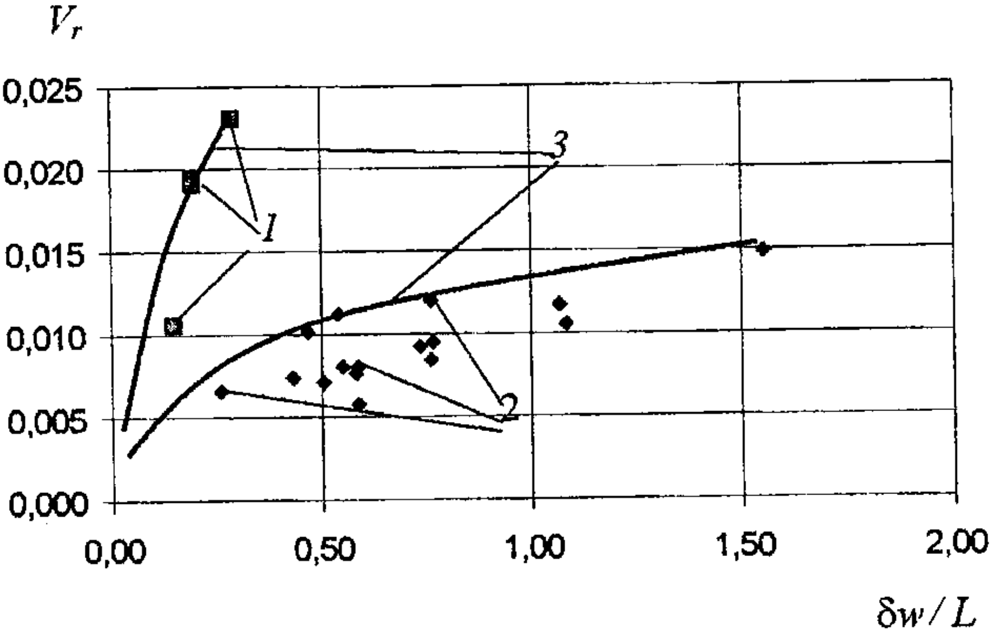


Fig. 8. Dependence of the efficiency index on the *dw/Lp* parameter: *1* – bulb profiles; *2* – rectangular and trapezoidal; *3* – envelopes for the most effective profiles of each type

On the Fig. 9 are shown the NPO PM modern heat pipes and enlarged scheme of its manufacture.

On the Fig. 10 is hyperheat -conducting void structure for the cooling of the electro – radio elements of the space craft devices. Hyperheat conducting porous structure exceeds on specific cold – productivity (in Wt on 1 kg of structure mass) the present seats of devices with heat pipes more than in two times.

On the Fig. 11 is the equipment for the heat pipes manufacture, but on the Fig.12 is a complex of the testing aids on the heat pipes ground experimental tryout, including those installed into the spacecraft and also the convertible radiators on the heat pipes.

References

1. Dvirniy V.V., Smirnov K.G. – Vasiliev and other. Experimental researches of the long-length, grooving heat pipes for the satellites honeycombs and their application in absorption refrigerator // *Report on the IX International Conference on the heat pipes* / Albuquerque, USA, 1995

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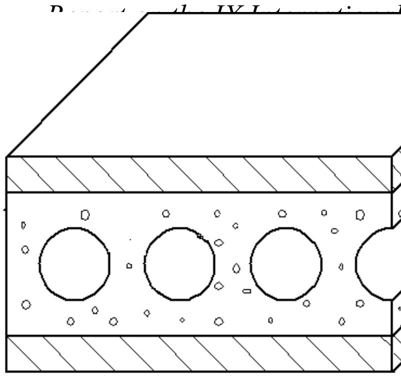

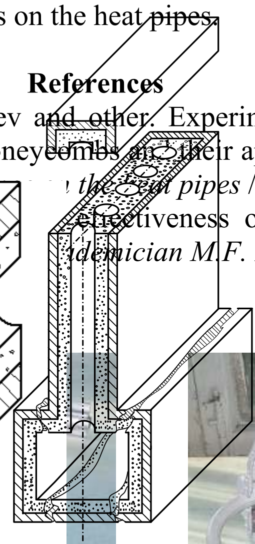

Equipment for the run – in of the gas – regulated heat pipes

Test bench for the heat pipes refueling by ammonia

Equipment for parameters check and for the run – in of aluminum heat pipes

Equipment for parameters check of gas regulated heat pipes

Fig.11. Equipment for heat pipes production

TRANSPORTATION

Transportation test bench on the PL-250N base

Spacecraft structure tryout on the transportation load action (airplane, car, railway). Solution of the task for minimization of the spacecraft start preparation by the stability check of the fight model to the action of the transportation dynamic loads on the production factory.
Band width: from 5 to 300 Hz;
Draft force: 4x25 ton

ZERO-LIFTRAJECTORY

Spacecraft structure tests on the Vibration Strength on the levels comparable with the vibration levels, arise at the launch vehicles engines and air burble on the atmospheric journey leg. Experimental verification of the spacecraft quality.
Bandwidth from 5 to 2500 GHz;
Druft force to 100 kN.

Vibration exciterВЭДС-10000

Spacecraft test on the levels of the acoustic pressure comparable with levels under the head fairing on the active journey leg. Experimental verification of the production quality of the spacecraft flight models.
$V=660m^3$
Peak level of the acoustic pressure is 154 dB

Reverberation acoustic chamber RK-660

SPACE

Tests of the transformed structure on the functioning in the conditions closed to the space (Weightlessness, extreme temperatures and vacuum). Degassing, leakproofness control. Equipped by solar radiation simulation, heat flow simulator, video control system.
$V = 120/400\ m^3$

Thermal vacuum chamberТБК-120, КВУ-400

Functioning control of multiple-link, transformed structures of the spacecraft mechanical systems at the weightlessness simulation.
The possibility of the test bench adaptation for the newly made mechanical systems.
The number of simultaneously controlled directions of the object movement : 3
$S = 250m^2$; h = 15 h.

The area for mechanical systems

Fig. 12. Complex of the testing aids for simulation of environment destabilizing factors