THEME 0: INTRODUCTION AND THE GENERAL CONCEPT OF LPT SYSTEMS

Features of LPT

Thrusters (LPE) with the level of thrust from 0,1 up to 1600 N relate to LPE of small thrust (LPT). Such LPE are used for orientation and stabilization of space vehicle in the space, corrections of their orbit, approaching and a docking with other space vehicles, and also for deceleration, descent and landing of space vehicle. Besides LPT can be used in support systems of cruise engine start (for creation of acceleration of space vehicle and support of upstream pressure in their pumps).

LPT can be devided by quantity of used propellant components on unicomponent and bicomponent.

Unicomponent LPT are characterized by type of fuel and a kind of its expansion.

Bicomponent LPT differ with type of fuel which can be autoigniting or not autoigniting.

The LPT (unicomponent and bicomponent) can work both in continuous, and in a pulse mode. Regime of engine operation is named *continuous* in time at which the specific impulse of an engine practically does not depend of a time.

The pulse mode of engine is such regime at which engine ignitions interleave with its cutoffs. The specific impulse of an engine generally depends on pulse duration and frequency.

For the majority of existing bicomponent LPTs the time of a continuous condition lays within the limits from units of seconds up to several thousand seconds, and a time in use at a pulse mode 0,01...1,00 sec.

Regimes of LPT operation can be devided as *a steadied* and *unsteady* pulse modes. At *steadied* regime the specific impulse does not depend on a serial number of an impulse, and at *unsteady* pulse mode depends of it. Apply also *a condition of single-pulses,* i.e. operational mode of the LPT with spacing intervals during which the engine comes in an initial state.

Dynamic parameters of the LPT are determined by speed of transients at start and engine cutoff, including setting time.

On specific impulse of the LPT working in a pulse mode, volumes of cavities of an engine from valves up to output cross-section of the injectors essentially influence. As the LPTs work in conditions of vacuum at spacing intervals more than 10...20 мs propellant components from the indicated cavities practically completely evaporate. At next engine ignition approximately 5...10 мs it is expended on filling of these cavities that worsen the dynamic parameters of an engine.

Alongside with requirements to the LPT, analogous with requirements to all LPE (large reliability, hight specific impulse, a small mass), the LPTs should fulfill to specific requirements:

1. Hight dynamic parameters: small values of response time and a turn-off time of the engine, what ensuring a small shut-down impulse;
2) Maximum precision of required thrust impulse;

3) Providing of functionability at large number of operation periods (for impulse LPTs).

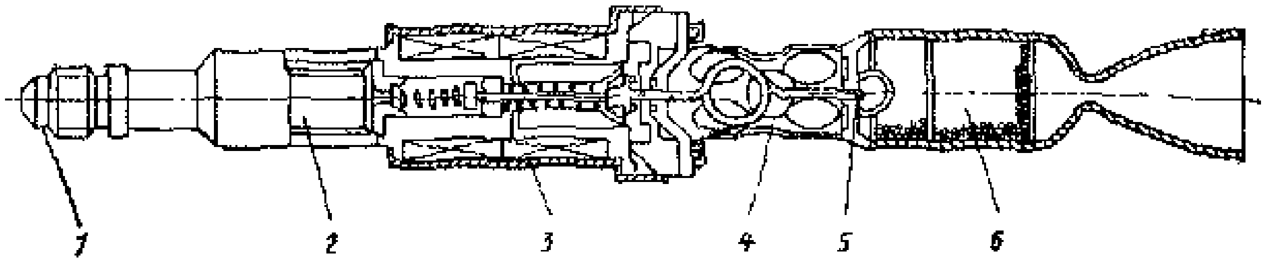
As well as all space engines, the LPTs should work safely in space environments, in particular in conditions of null gravity and at effect of micrometeorites.

The LPTs for the space vehicle, stabilized by rotation, should create $(2...10)\cdot 10^4$ pulses. For space vehicle with stabilization on three axes of an operating condition of the LPTs it is required $(2... 10)\cdot 10^5$ impulses by duration less 0,01c much heavily - is usual. Spacing intervals between impulses can be significant.

Unicomponent LPTs

Unicomponent LPTs on a construction it is easier as bicomponent, but worse of them on dynamic and energy performances.

In a construction of unicomponent LPTs it is possible to select following elements: the filter, the solenoid-operated hydraulic valve, the chamber with injectors and a catalyst (picture).



The design concept of the hydrazine engine:

1 - input of fuel;

2 - the filter,

3 - the valve;

4 - a thermal resistance;

5 - an injector;

6 - a catalyst

At the initial stage of control engineering and stabilization of an space vehicle have used unicomponent LPT, operating with concentrated hydrogen superoxides.

Example LPT, operating with 90 % hydrogen superoxides, is LPT of the geostationary satellite "Sincom" stabilized by rotation.

Spherical tanks made of aluminum with a high scale of purity (for decreasing of catalytic expansion of hydrogen superoxide at a long contact to walls of a tank). About 60 % of a volume of a tank took hydrogen superoxide, and a remaining volume - gaseous nitrogen with initial pressure 1,5 МПа. As completely to eliminate expansion of hydrogen superoxide in a tank it is not possible, on a tank the relief valve calculated on pressure 1,8 MPa is established. The chamber of expansion is separated from tanks by the solenoid-operated hydraulic valve. For expansion of hydrogen superoxide silver screens were used. Thrust was reduced from 17 N at initial tank pressure down to 5 N at the end of activity. Response time and made engine cutoffs about 3 mcs.

The basic problem by development of the indicated LPT it was selection for its valves of a structural material with a high scale of purity, with the low catalytic properties, ensuring its compatibility hydrogen superoxide.

Four LPT, working with hydrogen superoxide and developing thrust on 225 N, were used in a missile stage "Centaur" for creation of acceleration of a stage and, hence, pressure of propellant components an input in pumps before restart of the main LPE. Besides in the this stage applied two packets of LPT, working on the same fuel and creating thrust of 16 and 27 N.

Hydrazine LPTs. Application of a hydrazine instead of hydrogen superoxide allows to increase specific impulse of the LPTs approximately up to 30 %. Besides the hydrazine is more stable, than hydrogen superoxide. Therefore now the LPTs with hydrogen superoxide almost are completely superseded by hydrazine LPTs. Broad application of a hydrazine in the LPTs largely was promoted by creation of high-reliable catalysts with large resource, in particular catalyst "Shell - 405".

Example of hydrazine LPTs are engines for the landing unit of space vehicle «Viking - 75 ». Braking engines ensures deorbit and control of a position of the landing unit before opening of parachutes. It consist of two titanium hydrazine tanks with rubber diaphragmes for separation of a fluid and gas and 12 LPTs with catalyst. Thrust of engines decreases from 32 down to 14,7 N in process of pressure decrease in hydrazine tanks from 2,5 down to 0,95 MPa. In a structure landing engine unit, four LPT with the thrust varying from 39 down to 24 H, two hydrazine tanks. Initial pressure in tanks makes 3,4 MPa.

For LPT with small thrusts (0,1... 0,4 N) a width of nozzle of an injector for injection of a liquid hydrazine in the chamber is very small also the nozzle can get littered. In order to prevent it it is possible to evaporate a hydrazine (normal temperature of boiling of a hydrazine is 387 K).

Bicomponent LPTs

Bicomponent LPTs have a number of advantages at unicomponent. In particular for them are characteristic: longer resource; practically unlimited number of operation periods without aggravation of energy performances; higher specific impulse; lower temperature of a freezing of propellant components (for fuel N_2O_4 + MMH).

In bicomponent LPTs are used autoigniting fuel N_2O_4 + N_2H_4, N_2O_4 + MMH, N_2O_4 - aerozine-50, N_2O_4 + UDMH. These components ensure long storage. LPT with components O+H are created. Now the smallest American LPTs with fuel N_2O_4 + MMH are carried and have thrust 11...25 N.

Widely apply the bicomponent LPTs operating in a pulse mode. The main advantage of engine operation in a pulse mode is, that the engine with large thrust can be used for creation of a small impulse of thrust. For obtaining different small impulses of the thrust use engine runs with constant thrust (Pv = const), but with different duration of an operation period. To a significant decreasing of thrust apply also a simultaneous modification of duration of an operation period and engine thrust (for example, its decreasing down to 10 % $_{\text{Рп ном}}$). In particular, for a decreasing of LPT thrust ensure decreasing of square of injector holes.

Pulse mode of activity apply, as a rule, only to the LPTs working on autoigniting fuels.

One of advantages of impulse LPTs is the capability of operating for a long time without effective cooling if the temperature of walls of a engine during a spacing interval decreases up to reference temperature at start.

Frequency of operation periods of the LPT influece upon their parameters because of effect of residual temperature of a wall of the chamber from the previous operation period. The less spacing interval between operation periods, the above residual temperature of a wall at a consequent operation period, is less intensity of a heat flow from gas to a wall.

Performances of LPT start depend of conditions of vacuum. At start in vacuum condition the thruster propellant ignition delay is increasing as to start on a sea level.

The specific impulse at a pulse mode is lower, than on continuous, and difference is increasing with increase of frequency of impulses and can make up to 50 %.

At presence on space vehicle several LPT (for example, apogee LPT and stabilization LPT) it is rational to use common tanks as thus large compactness engine unit is ensured.

At development of bicomponent LPTs it is necessary to reckon with presence not burned particles of propellant components and with clogging fuel lines. In nitrogen tetroxide at long storage the gel which can penetrate through filters and narrow cross-sections and block metering injectors and capillary channels of supply; danger of this clogging can be reduced by careful clearing of propellant components.

Fuel lines of small diameter (less than 0,25 mm) can choke also with adjournment of the nonvolatile remains at evaporation of a propellant component at its release in vacuum because of a deficient leakage of the valve.

Chambers of LPT

Chambers of LPT can be distinguish by using a constant or the variable area of through passage section of the injector, and also the chamber with one or several injector elements.

Chambers with the changeable area of a flow area are named as *throttled*. As a rule such chambers have one injector element.

Chambers with a constant flow area of the mixing head and several injectors are simple in design, but have some most values of response time and a releasing time of thrust by reason of a valves location on input in the head and presence of a fixed volume between valves and the head. This volume should be as it is possible smaller.

In chambers of the LPT apply both - centrifugal, and spray injectors.

In chambers of LPT with thrust 10 and 400 N in space vehicles "Symphony" and "Galileo" are used the mixing head with one bicomponent centrifugal injector. In the chamber there is the coaxial rotated jet of propellants ensuring conical dispersion of drops. The injector ensures also an internal cooling of walls of the chamber by creation of excess of an oxidizer in near wall bed of products of combustion.

In the chamber of LPT R-1 E-3 (additional engine of jet control system "Space Shuttle") one double components injector with interfere jets of an oxidizer and fuel is used. The collecting channel of the head has a small volume that ensures:

1) Fast filling and a draining of a collecting channel;

2) Minimizing change of an engine performance as result of saturation of propellants by displacing helium;

3) Eliminates large pressure differentials in the chamber at firing of fuel during start.

At invariable pressure in fuel tanks for thrust variation LPT apply a burner plate with the changeable area of injection of propellants. It is the easiest to ensure it if the mixing head represents double components injector which mobile element changes flow areas of injection for both propellants.

In this case in a specified range of a thrust variation the pressure differential on injectors can be saved practically invariable. With decreasing of the flow rate of propellants chamber pressure and, hence, completeness of combustion of fuel are reduced. Such head was applied in the chamber of landing LPT of a lunar stage of the spacecraft "Apollo". This engine ensured thrust reduction in 10 times in compare to the thrust at nominal regime of LPT operation.

In engines RS-2101C of space vehicle "Viking - 75" and R-4D-11 spray injectors with interfere jets of an oxidizer and fuel are used. Injectors are placed on the single round having middle radius between center and a wall of the combustion chamber.

At operating of the LPT the temperature of the head of the chamber should be such that the capability of a boiling-up of propellant components in its cavity was excluded. Usually thin-walled cylindrical punched prorate is set for this purpose between the head and the combustion chamber. Decreasing of a heat flow in the head and simultaneously increase of completeness of combustion of fuel is provided at manufacturing of the mixing head from a plate in which etch the numerous fuel channels ensuring its porous cooling both which causes uniformity and accuracy of input of propellant components in the combustion chamber.

The head of some chambers of the LPTs made of aluminum alloys. Such material used, in particular, in the head of the chamber of auxiliary engines MA-109 of the spacecraft "Apollo" with the thrust 450 N. Aluminum alloy 2219-T6In for the head of engine chamber RS-2101 was applied. As the combustion chamber of this engine has been made of beryllium, between a burner plate and the combustion chamber the sealing gasket has been placed.

The head of engine chamber R-40 make of steel and aluminum alloy, the head of chamber LPT with the thrust 10 and 400 N of space vehicles "Symphony" and "Galileo" — from stainless steel, and in engines R4D-11 and R-1E-3 — from titanium alloy.

More often the head connect to the combustion chamber by welding (if docked walls are made of welded materials).

In combustion chambers and nozzles of chambers of LPTs R-40A, R-4D-11, R-1E-3, R-6C and R-6B welding are used. In chambers LPT with the thrust 10 and 400 N for satellite "Symphony" all connections are made by the electron beam welding ensuring high air-tightness of joints.

Chambers of bicomponent LPT at continuous operational mode on fuel N_2O_4 and MMH at thrust Pv = 2,2...445 N provide specific impulse Ispv = 2735...2825 m\s.

At a pulse mode of the LPT operation the specific impulse is lower. As less time of impulse of thrust, then lower specific impulse is. Time of impulse is determined by time of supply of voltage for fuel valves, At impulse time 6...20 мs the specific impulse of the LPT is usually about 1860...2350 m\s.

High specific impulse of engine R-1E-3 (2350 m\s) at duration of electric impulse 40 мs is caused by a small volume of an internal cavity of the mixing head.

The mass flow of propellant components has extremely low values. For example, in LPT R-6B oxidizer flows and fuel make only 0,5 and 0,3 g/s accordingly.

Конструкция камер ЖРДМТ зависит от метода охлаждения. Используют регенеративное, абляционное, внутреннее (пленочное), лучистое и комбинированное охлаждение.

The design of chambers of the LPTs depends on a method of cooling. Regenerative, ablation, internal, radiation and combined cooling are used.

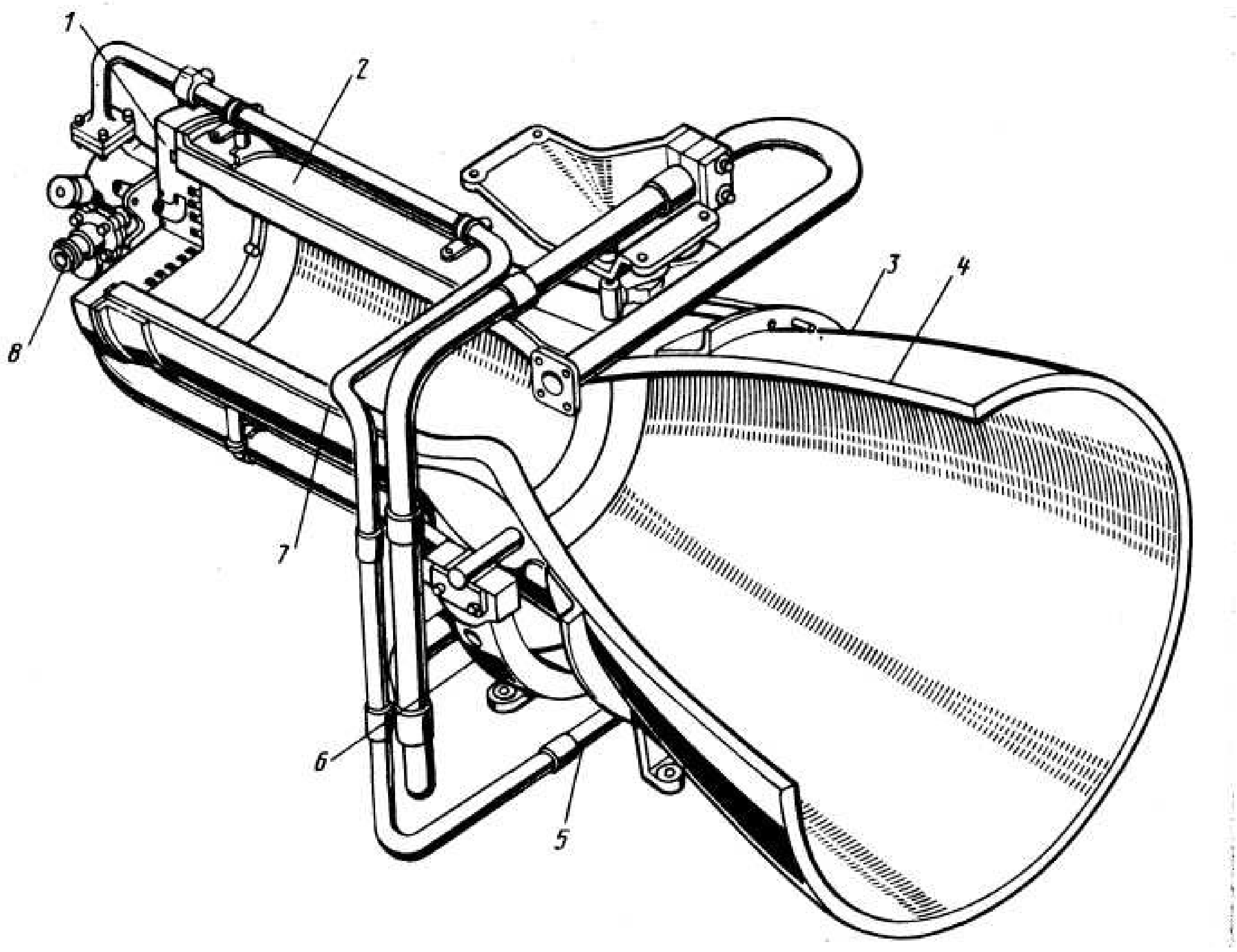
The most effective is *regenerative* cooling. But its realization in chambers of the LPTs is difficult. At small thrust and small chamber pressure the ratio of density of a heat flow and a surface of the chamber causes high temperature of the cooling agent. Because of the small flow rate of the cooling agent its speed in cooling channels appears insufficient for cooling of walls of the chamber. In result the temperature of walls of the chamber and the cooling agent can grow up to prohibitive values. Thus there is a decomposition or film boiling of the cooling agent.

The chamber of the LPT of space vehicle "Mariner-9" had the thick-walled combustion chamber from beryllium with high heat conduction with external flowing cooling.

Ablation cooling of chambers of the LPTs provides simplicity of their design and the minimal heat flow in an environment. Chambers with ablation cooling have large weight in comparison with the chambers having radiation cooling (because of thick layer of an ablation material). The weight of the chamber with ablation cooling depends on time of its operation. At a large operating time the weight of such chambers can become excessive.

Абляционное охлаждение применяли в ряде ЖРД КК "Аполлон" (во взлетном ЖРД лунной ступени, тормозных ЖРД и др.). Такой вид охлаждения применяют в камере сгорания и сопле основного ЖРД (рис) и ЖРД ориентации ступени разделения головных частей МБР M-X, причем камеру изготавливают из монолитной бериллиевой заготовки.

Ablation cooling was applied in series LPT in the spacecraft "Apollo" (in main LPT of a lunar stage, braking LPT, etc.). Such kind of cooling apply in the combustion chamber and the nozzle of the main LPT (picture) of a stage of separation of nose cones of rocket M-X, and the chamber make of monolithic beryllium preparation.



The main LPT of a stage of separation:

1 - the mixing head; 2 - a body of the chamber; 3 - cevlar body of the nozzle; 4 - a layer of an ablation material of low density on an internal surface of the nozzle; 5 - flexible connection; 6 - the gimbal mount; 7 - a layer of an ablation material on an internal surface of the combustion chamber; 8 - main valves of an oxidizer and combustible.

On an internal surface of the chamber of combustion and nozzle put a layer of ablation material. As ablation material is used material on the basis of phenol pitch and dioxide of silicon.

Radiation cooling provides simplicity of a design and rather small weight of chamber LPT in comparison with ablation cooling, is especial at the big operating time of the engine. At radiation cooling the big thermal flow to an environment is created. For chambers with radiant cooling the high temperature of walls of the chamber is characteristic, that causes necessity of application of refractory metals (molybdenum, tungsten, tantalum and niobium) and alloys on their basis. Characteristics and service life of chambers with radiation cooling are determined by the chosen heat resisting both refractory metals and coverings. Thus coverings should have enough high adhesion.

Limitation of temperature of walls achieve also by selection of a corresponding combination of the mixing head and a configuration of the chamber of combustion.

The chamber of LPT for spacecraft "Apollo" with a thrust 441 N MA-109 was made from niobium with coating. On the nozzle throat put coating by $MoSi_2$. To analogous chambers applied molybdenum alloy containing additives Ti and Zr, or molybdenum with coating by $Mo\,Si_2$.

For manufacturing of the nozzles using radiation cooling, also apply high-melting and high-temperature metals.

The nozzle of the chamber of the LPT of space vehicle "Mariner-9" was produced from heat steel with dopes of a cobalt, such nozzle in an operating time heated up to temperature approximately 1375 K.

Except for small chemical durability to yields of combustion refractory metals are expensive materials, and manufacturing from them chambers differs complexity owing to a brittleness of the specified metals. Development resistant to oxidation of coatings of refractory metals with large safe life represents particular difficulties.

In some cases coating not only protects a surface of a wall from oxidation, but also increments its emissive power that causes additional decrease of temperature of a wall. Such properties the layer of alumina put on a surface of a wall from nickel alloy has, in particular.

For creation *of a film cooling* of walls of the combustion chamber and the nozzle on periphery of the head of the chamber place the injectors creating near wall layer of a lot of oxidizing agent or combustible (last apply more often). For example, in the head of chamber LPT R-4D-11 alongside with 8 two spray nozzles with facing jets of an oxidizing agent and fuel there are 16 injectors for maintenance of a film cooling.

The film cooling was used by an oxidizing agent, as mentioned above, for walls of a cylindrical part of combustion chamber LPT 10 and 400 N the artificial satellite "Symphony" and is used by a thrust for walls of the chamber auxiliary LPRE of rocket "Minitmen III" for what it is spent fuel (approximately 13 % of the general flow rate). Walls of chamber and its mixing head are made from niobium alloy SCb-291. Selection of this alloy is caused by its inertness in relation to nitric acid which can be formed at the long-lived storage of nitrogen tetroxide.

Chambers with a film cooling maintain high values of area density of a heat flow and have the underload values of the specified density in a surrounding medium. For such chambers the losses called by decrease of efficiency of combustion in near wall a layer are characteristic.

Film cooling frequently apply in a combination with radiation one. Thus the chamber make also of refractory metals. For example, at the chamber with a film cooling, made of the niobium, the permissible temperature of walls makes

2030K,

Specific cooling was applied to chamber LPT RS-2101C of space vehicle "Viking - 75". Fuel it was sputtered on an internal surface of walls of a convergented part of the nozzle, it was evaporated, taking from the heat flows spreading on a wall from the specified part of the nozzle to a cylindrical part of the chamber. This distribution was provided with that made the combustion chamber of the beryllium having very high heat conduction. In a cylindrical part of the chamber heat is immersed by the volatilizing film veil fed to it on the part of the convergented part of the nozzle. Such cooling term *as internal* regenerative cooling.

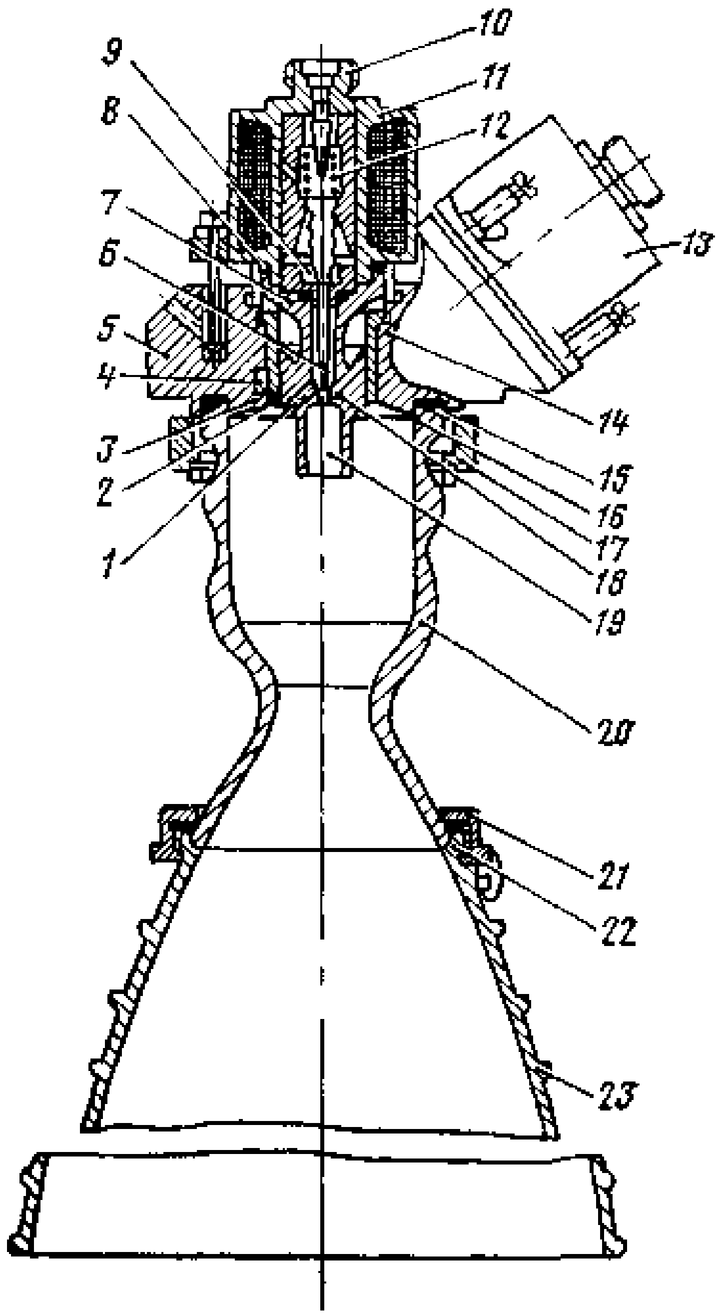
The combination of internal and radiation cooling is applied in the chamber of pony motor DU of jet control system of spacecraft " Space Shuttle ". The wall of the combustion chamber and the nozzle have a layer of products of combustion a lot of fuel. It implements change of an angle of injection of a part fuel, going on a film cooling. The big angle improves cooling in a zone of the joint of the spray head and the combustion chamber that results in decreasing of temperature of the head at an operation period of the engine. The layer of thermal insulator with low heat conduction can work at temperature of walls of the combustion chamber 1700 K. At maximum temperature of a wall in the critical cross-section of the nozzle 1285 K safe life of the chamber $7{,}2 \cdot 10^5$ s is provided. Maximum time of a continuous work makes 125 s. Maximum temperature of walls of the chamber of LPTs R-40A, R-4D-11, R-1E-3, R-6C and R-6B rather low (over the range 1313...1563 K). It allows to ensure adequate supplies of strength at manufacturing of walls of the combustion chamber and the nozzle from alloys of niobium and a titanium.

In the chamber of LPT RSPE ensuring maneuvering of nose cone of rocket "Minitmen III", the head, the combustion chamber and the nozzle made also of niobium (computational temperature of the chamber 2030 K).

In some of chambers are used coating R-512A superimposed by a method of fusing. It is designed for maximum temperatures 1800...1920 K. Thickness of superimposed coating — approximately 75...125 microns.

For maintenance of temperature of the chamber auxiliary LPT of lunar space vehicle "Serveyer" between operation periods in working range on the biggest part of an external surface of the chamber put coating by gold.

On picture it is shown LPT of spacecraft "Lisat" which chamber has radiation cooling.



Design of engine R-4D:

1 - eight holes of an oxidizing agent;

2 - eight main injectors of fuel;

3 - eight injectors of fuel for cooling;

4 - collecting channel of fuel;

5 - head;

6 - input of an oxidizing;

7 - inserts;

8 - insulator;

9 - saddle;

10 - valve of an oxidizing;
11 - electromagnet coil;
12 - spring;
13 - valve of fuel;
14 - input of fuel;
15 - seal;
16 - eight injectors for cooling of the prechamber;
17 - ring;
18 - hole of an oxidizing;
19 - prechamber;
20 - chamber;
21 - ring;
22 - nozzle;
23 - nozzles

The combination of internal and radiation cooling is applied in LPT R-4D. The part of fuel in redundant quantity acts in near-wall layer, that also improves cooling in a zone of section of a mixing head and the combustion chamber. The minimum temperature of walls of the combustion chamber at continuous operational mode makes 1300 K.

Combined (regenerative, internal and radiation) cooling of chambers of the LPRE of an artificial satellite "Symphony" thrust 10 and 400 N rather effectively. Feature of cooling of the indicated chambers consists that in the chamber 400 N regenerative cooling by fuel is applied by thrust to area of a port of the nozzle, and in the chamber thrust 10 N — for the lower part of the combustion chamber.

Radiation cooling is applied for made of nymonic a port and an extending part of the nozzle of chambers of the LPRE with thrust 10 and 400 N an artificial satellite "Symphony".

Maximum time of continuous activity of the chamber with thrust 10 N exceeded 3•10^3 s at bench firing tests. The invariable thermal condition of the chamber of the LPRE with thrust 400 H with the combined cooling indicated above also was supplied at a long-period operation (more than 10,8•10^3s). The phenomenon of thermal absorption is not observed almost. At a thickness of a wall of the chamber of 1,5 mm its thermal capacity is insignificant. The temperature of fuel in a channel of cooling of the chamber after engine cutoff increased only on 10 K.

The nozzle of the chamber of the basic LPRE of stage M-X make from cevlar.

Some LPT can work on the various fuels. For example, hydrazine and aerozin-50 can be used except MMG in engine R-4D-11.

LPT (and, hence, a chambers) can work both in pulse and in continuous modes. The pulse mode is used in the core for manoeuvres of control by a rule in space and on a roll. Feature of a pulsed operation is rather small value of an impulse of the thrust, created at one cycle of activity even if the chamber advances rather large thrust. It allows to avoid the long operational modes of the chamber making more rigid to its cooling. Besides, it is possible to supply various values of an impulse of thrust at constant thrust by change only time of a cycle of activity. However the activity pulse mode imposes limitations on propellant selection (are fulfilled LPE repeated actuation only on self burning propellants) and as it was already marked, causes decrease of specific impulse of the chamber. LPREs of large thrust at fuel components supply under manifold pressure of tanks at idle pumps can get thrust, corresponding to thrust LPT. For example, at such operational mode of LPRE RL-10 supplies thrust 854 H and specific impulse in vacuum about 4000 m/s.

Values K_m for fuel N_2O_4 + MMH for majority LPT are chosen equal 1,60… 1, 65 (with the tolerance ± 0,03... 0,05).

It is possible to increase pressure $p_к$ for reduction of the sizes and weight of chamber LPT, but high pressures $p_к$ lead to toughening of requirements to cooling, especially in the field of a nozzle port.

Acoustic cavities (acoustic resonant dampers) take places on periphery of a mixing head for damping of HiFr-fluctuations at combustion in the combustion chamber of some ЖРДМТ (R40A, R-4D-11, RS-2101C etc.).

The dynamic stability of combustion is achieved by means of acoustic cavities supplying almost full tolerance to all natural and artificial disturbances, and also a stability of chamber in a broad band of operating conditions, including transient modes.

Number of LPT has very large resource, for example, operating time of LPT R-4D on a nominal mode can reach $3,6 \cdot 10^6$ s. Resource of auxiliary engines of control system “Space shuttle" also is planned to 10^6 s by use of improvement of technology of chambers and methods of deposition of sheetings, and also advanced methods of operational service.

Resource of the chamber depends not only on used constructional materials and covers, but also from the chosen operates parameters. In particular, decreasing of temperature of products of combustion in the chamber leads to increasing its resource.

Usually the plane of output sections of the nozzle of chambers LPT is perpendicular their centerline. However the basic and auxiliary engines of jet control system of "Space shuttle" are drowned in a ship fuselage, and their output section is profiled flush with a fuselage surface. There are 17 various corners of a shear of nozzles for the cores and for auxiliary LPREs because of a various positions of chambers concerning.

The axis of the nozzle of the chamber of the LPT usually is continuation of an axis of the combustion chamber, but the nozzle can be disposed under a corner (in some cases under a large corner (to 100 °)) to continuation of an axis of the combustion chamber; need for it can arise first of all for the LPRE of system of a course. On layout conditions output the nozzle section can have the rectangular form (for example, with a ratio of lengths of the parties, equal to two).