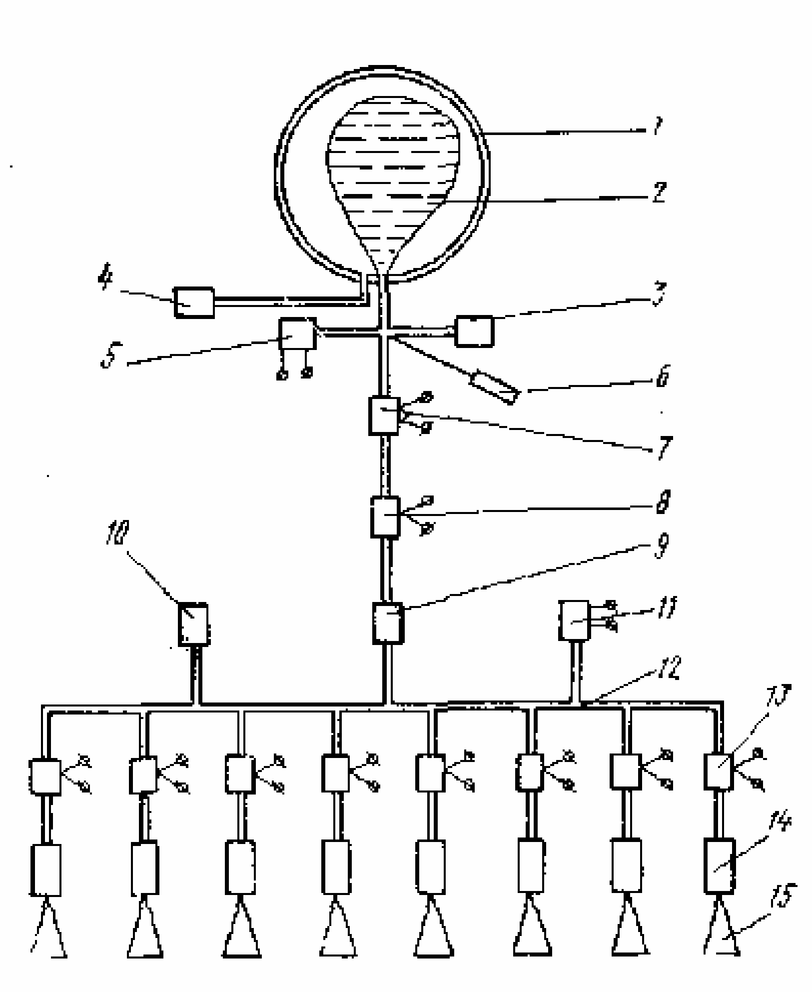
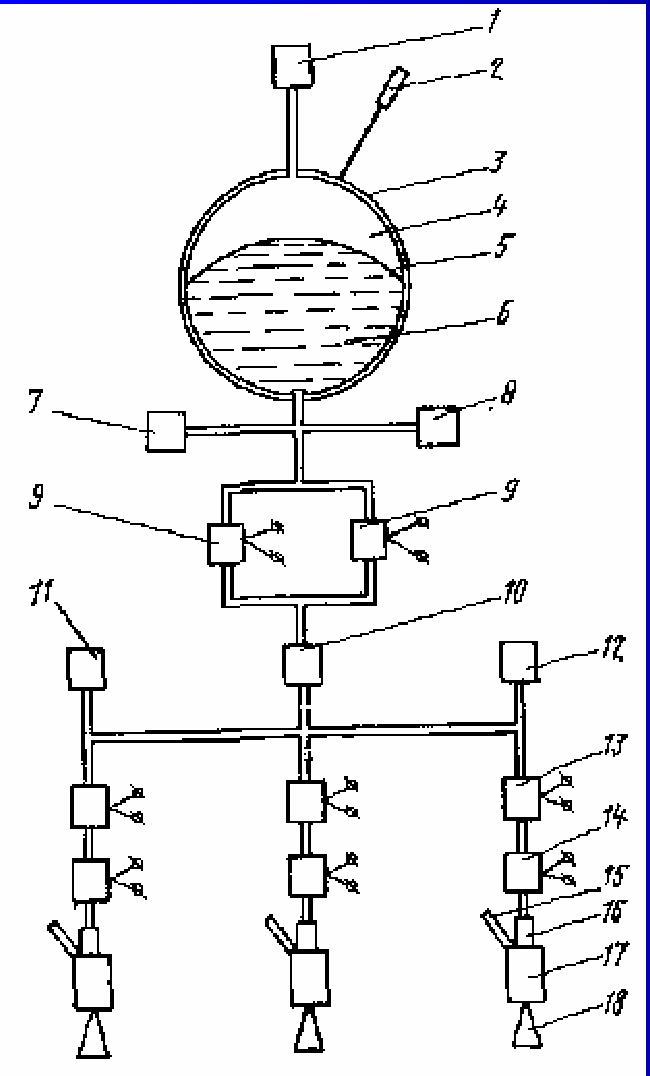
MONOPROPELLANT THRUSTERS



1 - a fuel tank;
2-elastic expulsive bag;
3-filling-draining valve;
4, 10-valves of leak check;
5, 11-pressure transducers of propellant;
6-temperature detector;
7-electric heater;
8-starting valve;
9-filter;
12-collector;
13-control electric valve;
14-chamber of decomposition with catalyst;
15-nozzle

Fig. 3. 26. The scheme of a jet system on liquid monopropellant:

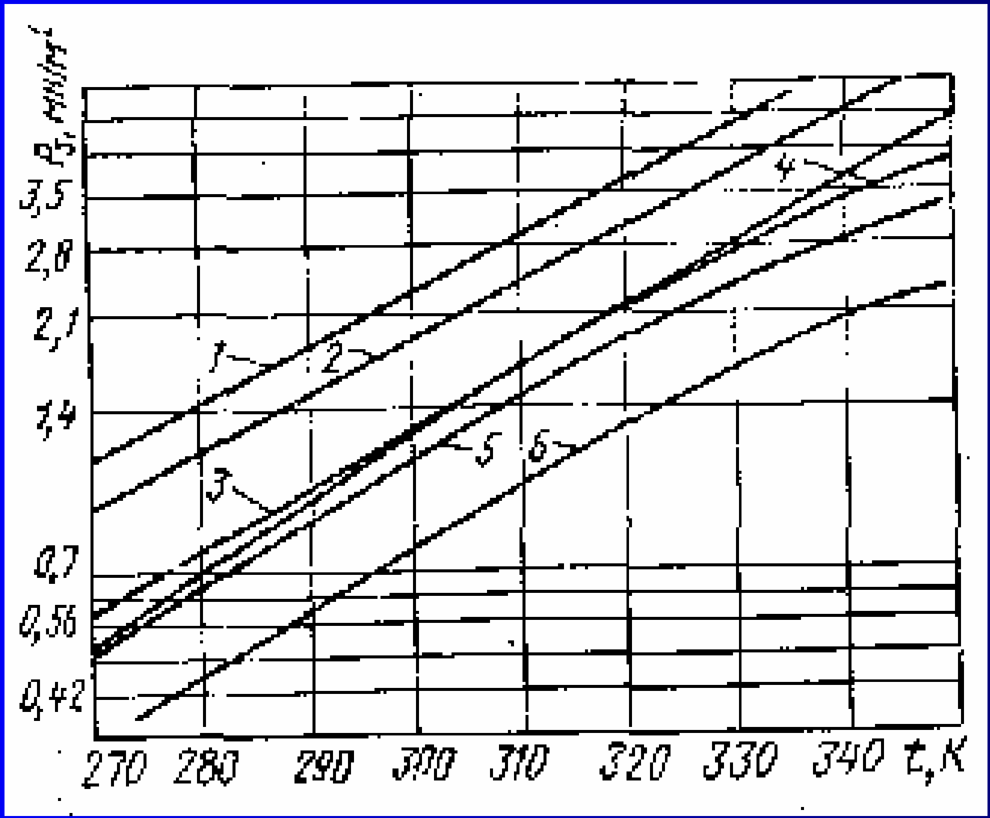
MONOPROPELLANT THRUSTERS



1-refuelling valve of nitrogen;
2-temperature detector;
3-fuel tank;
4-cavity for accommodation of a propulsive mass of pressurization - of nitrogen;
5-elastic separator;
6-cavity for accommodation of propellant - of a hydrazine;
7, 11-pressure transducers of propellant;
8-refuelling valve of propellant;
9-hydrovalve;
10-filter;
12-valve of leak check;
13, 14-Doubled valves of the engine;
15-temperature detector;
16-heater;
17-chamber with catalyst of decomposition;
18-nozzle

Fig. 3. 27. The scheme of a jet system on liquid monopropellant for orbit correction of American satellite ERTS

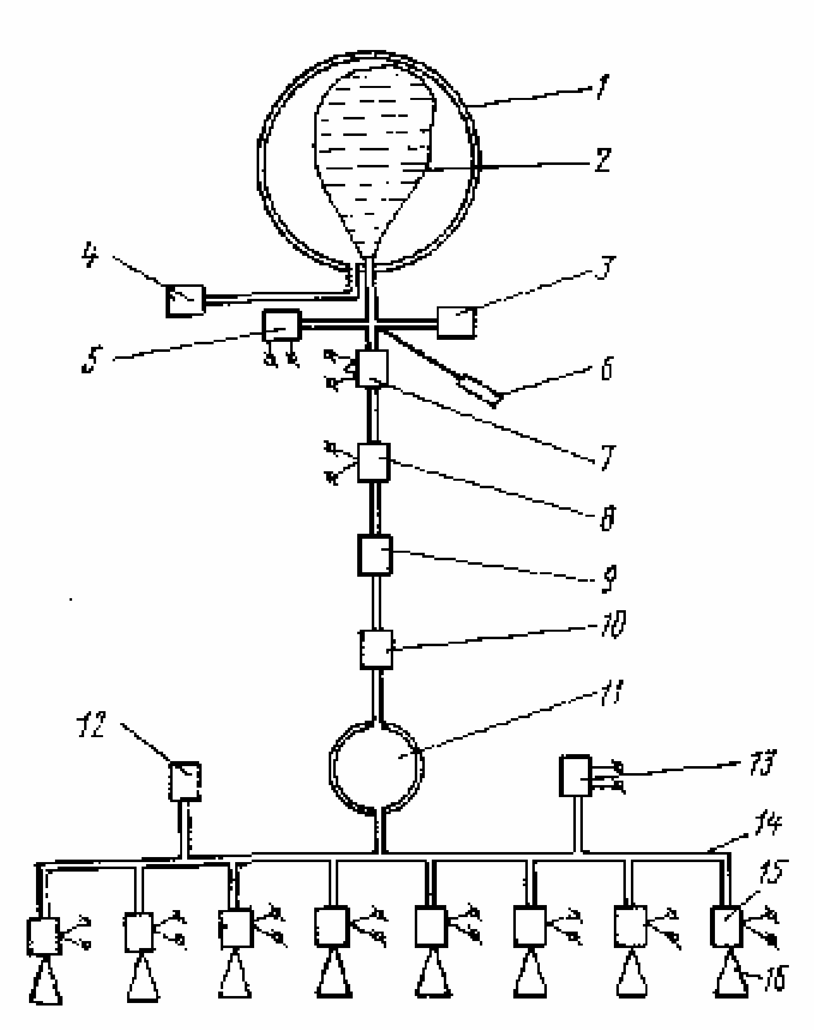
MONOPROPELLANT THRUSTERS



1 - constant boiling mixture of 43,2 % CH2F2+51,8 of % CF3CF2Cl ("genetron"115);
2 - CH2F2 ("genetron"32);
3 - CHClF2 (a freon 22);
4 - NH3 - (ammonia);
5 - CF3CF2Cl;
6 - CCl2 F2, (freon 12)

Fig. 3 28. Dependence of pressure of saturated steams on temperature of a propulsive mass:

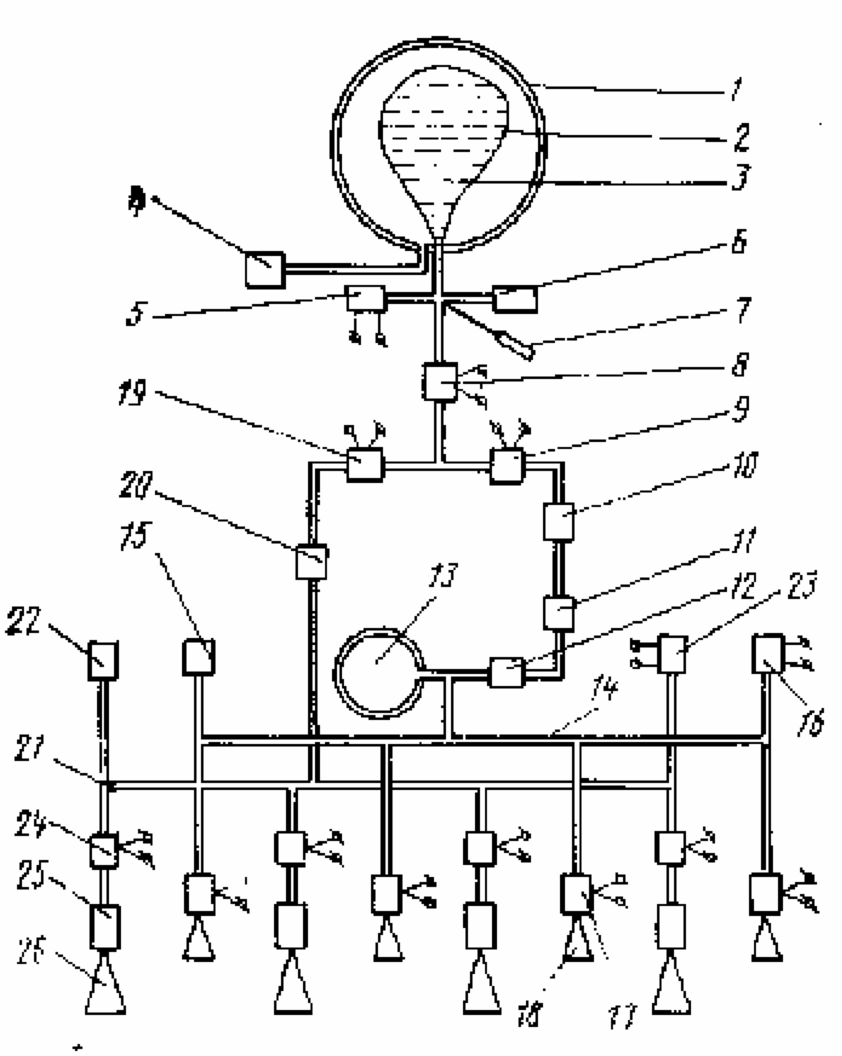
MONOPROPELLANT THRUSTERS



1 - a fuel tank;
2 - an elastic expulsive bag;
3 - the filling-draining valve;
4, 12 - valves of leak check;
5, 13 - pressure transducers of propellant;
6 - a temperature detector of propellant;
7 - an electric heater:
8 - a starting valve;
9 - the filter;
10 - the gas generator;
11 - a receiver;
14 - a collector;
15 - the electric valve;
16 - a nozzle

Fig. 3.29. The scheme of a jet system on liquid monopropellant with preliminary gasification of propellant:

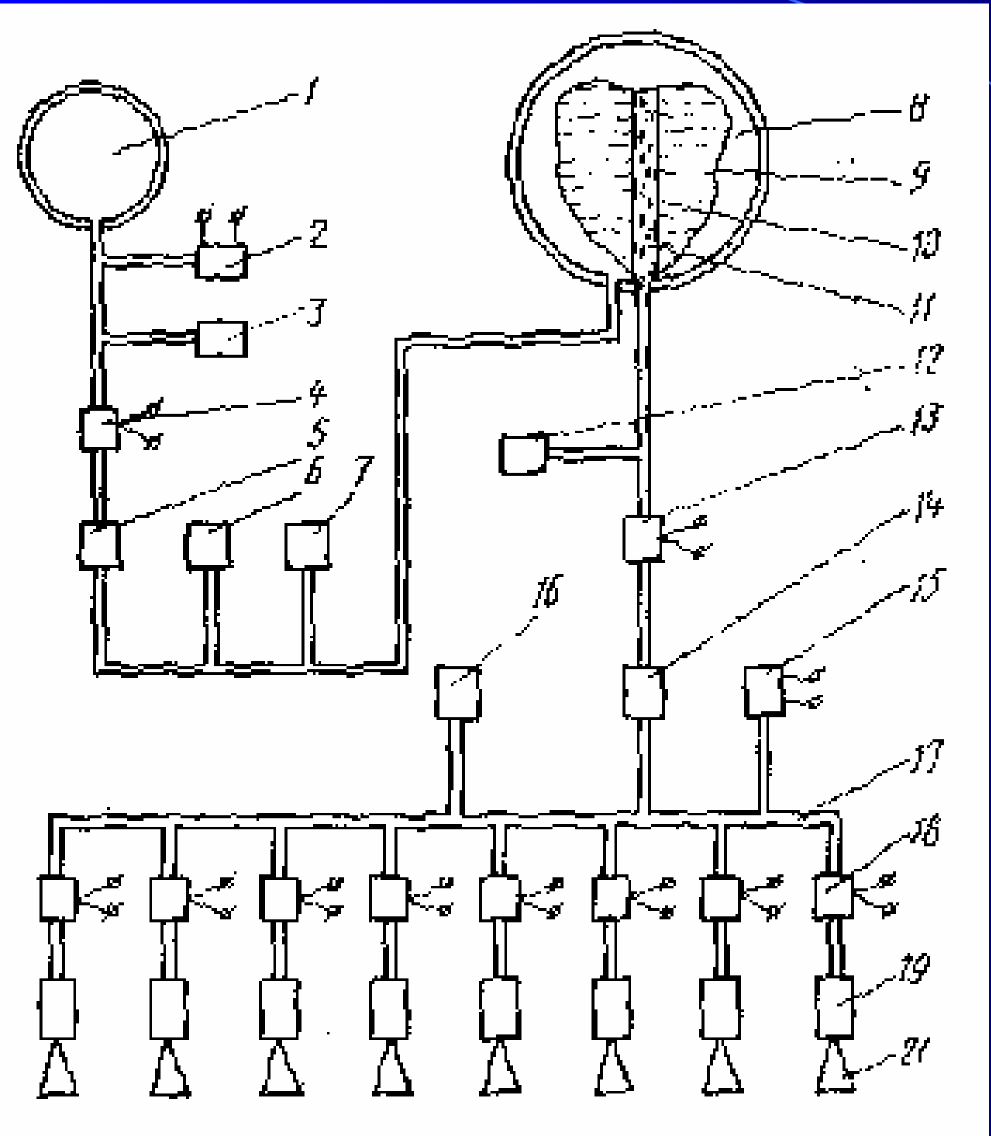
MONOPROPELLANT THRUSTERS



1 - a fuel tank;
2 - an elastic bag;
3 - propellant;
4 - the fill valve of a of pressurization mass;
5, 16, 33 - pressure transducers of propellant;
6 - the filling-draining valve;
7 - a temperature detector;
8 - the heater;
9, 19 - starting valves;
10, 20 - filters;
11 - a reverse valve;
12 - the gas generator;
13 - a receiver;
14, 21 - collectors;
15, 12 - verifying valves;
17, 24 - electric valves of engines;
18, 26 - nozzles;
25 - the chamber of decomposition

Fig. 3. 30. The scheme of a jet system on liquid monopropellant with engines of rigid and soft stabilization:

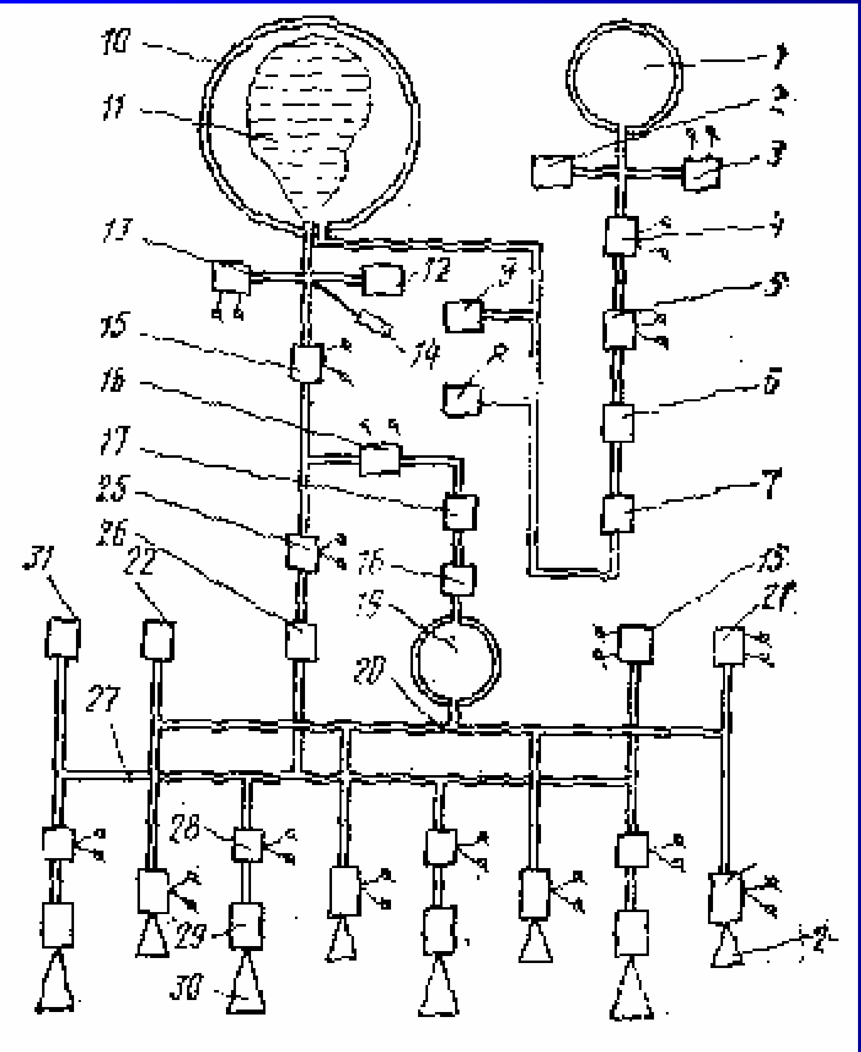
MONOPROPELLANT THRUSTERS



1 - a bottle with pressure gas;
2, 15 - pressure transducers;
3 - the charging valve;
4, 13 - starting valves;
5 - the pressure regulator:
6 - the relief valve;
7, 16 - valves of leak check;
5 - a fuel tank;
9 - a dividing bag;
10 - propellant;
11 - the intaking device;
12 - the filling-draining valve;
14 - the filter;
17 - a collector;
18 - the control electric valve;
19 - the chamber of decomposition;
20 - a nozzle

Fig. 3.31. The scheme of a jet system on liquid monopropellant with constant thrust of control engines:

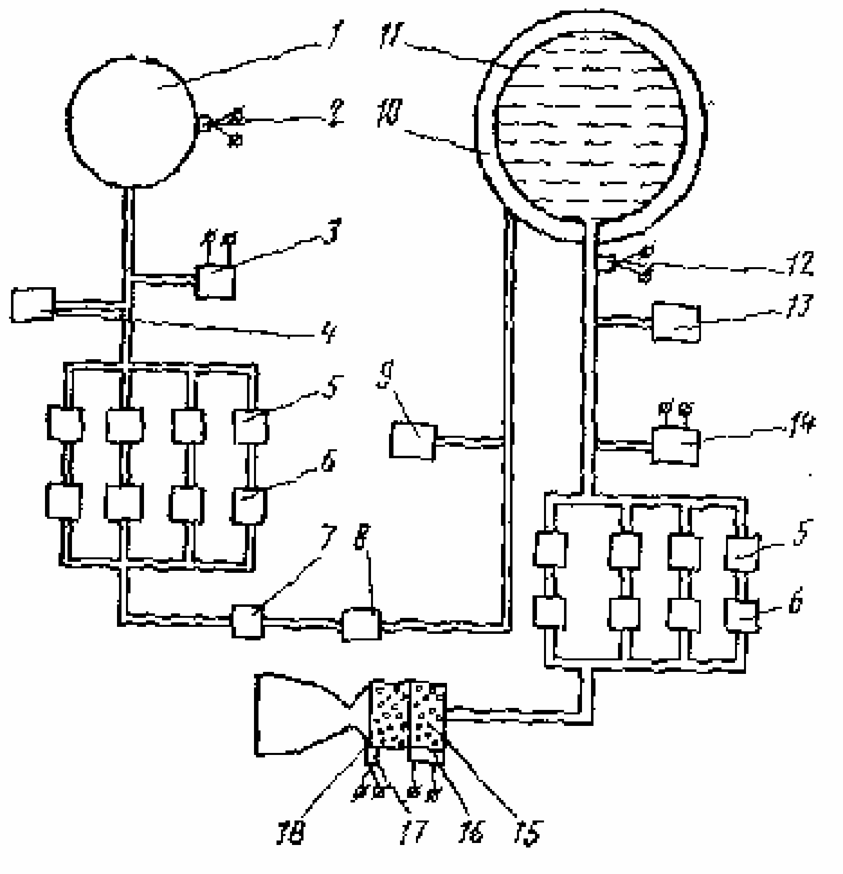
MONOPROPELLANT THRUSTERS



1-bottle with pressure gas;
2 - the refuelling valve;
3, 13, 21-pressure transducers;
4, 15 - heaters;
5, 16, 25-starting valves;
7-pressure regulator;
8-relief valve;
9, 22, 31 - valves of leak check;
10-fuel tank;
11-dividing bag;
14 - a temperature detector;
17-reverse valve;
18-gas generator;
19-receiver;
20, 27-collectors;
23, 25-control electric valves;
29-chamber of decomposition;
24, 30-nozzles

Fig. 3. 32. The scheme of a jet system on liquid monopropellant with engines of rigid and soft stabilization of constant thrust:

MONOPROPELLANT THRUSTERS



1-bottle with pressure gas;
2-temperature detector of gas in a bottle;
3-pressure transducer of gas;
4-refuelling valve;
5-Starting valve;
6-cut-off valve;
7-filter;
8-pressure regulator of gas;
9-verifying valve;
10-tank with a hydrazine;
11-elastic container;
12-temperature detector of propellant;
13-refuelling valve of propellant;
14-pressure transducer of propellant;
15-rocket engine;
16-pressure transducer of gas in the engine chamber;
17-sensor of temperature;
18-catalyst

Fig. 3.33. The scheme of correcting propulsion system on liquid monopropellant - a hydrazine of american space vehicle; "Mariner":

MONOPROPELLANT THRUSTERS

Engines with catalytic decomposition of a hydrazine cover following the range of parameters:

Thrust 0,09 - 1400 N;

Specific impulse 2200 - 2400 m/s;

Full operating time 18000 s;

Quantity of actuations 10^6;

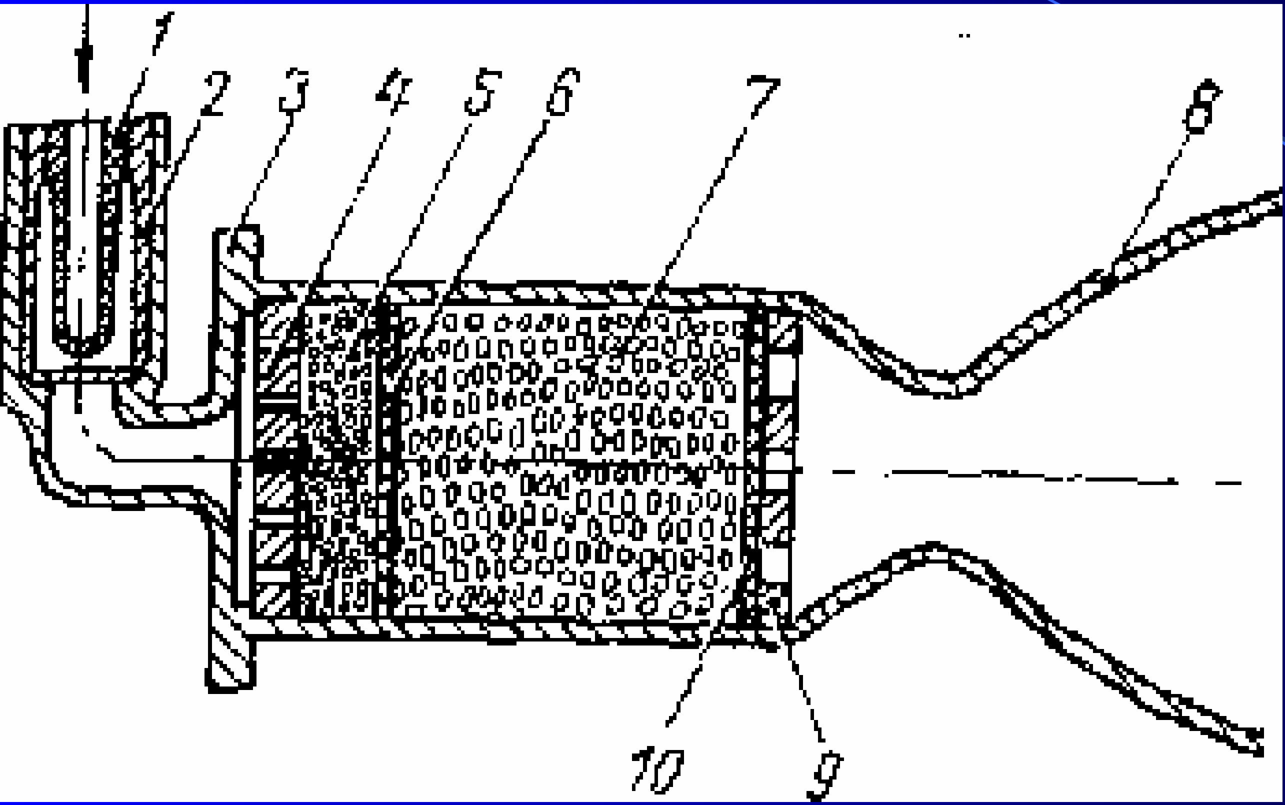
Total impulse 182000 N.s;

$\tau_{0,9}$ = 0,017 - 0,025 sec;

$\tau_{0,1}$ = 0,020 - 0,025 seconds.

At thrust of engines more than 1500N, it is necessary to use engines with thermocatalyc decomposition of a hydrazine.

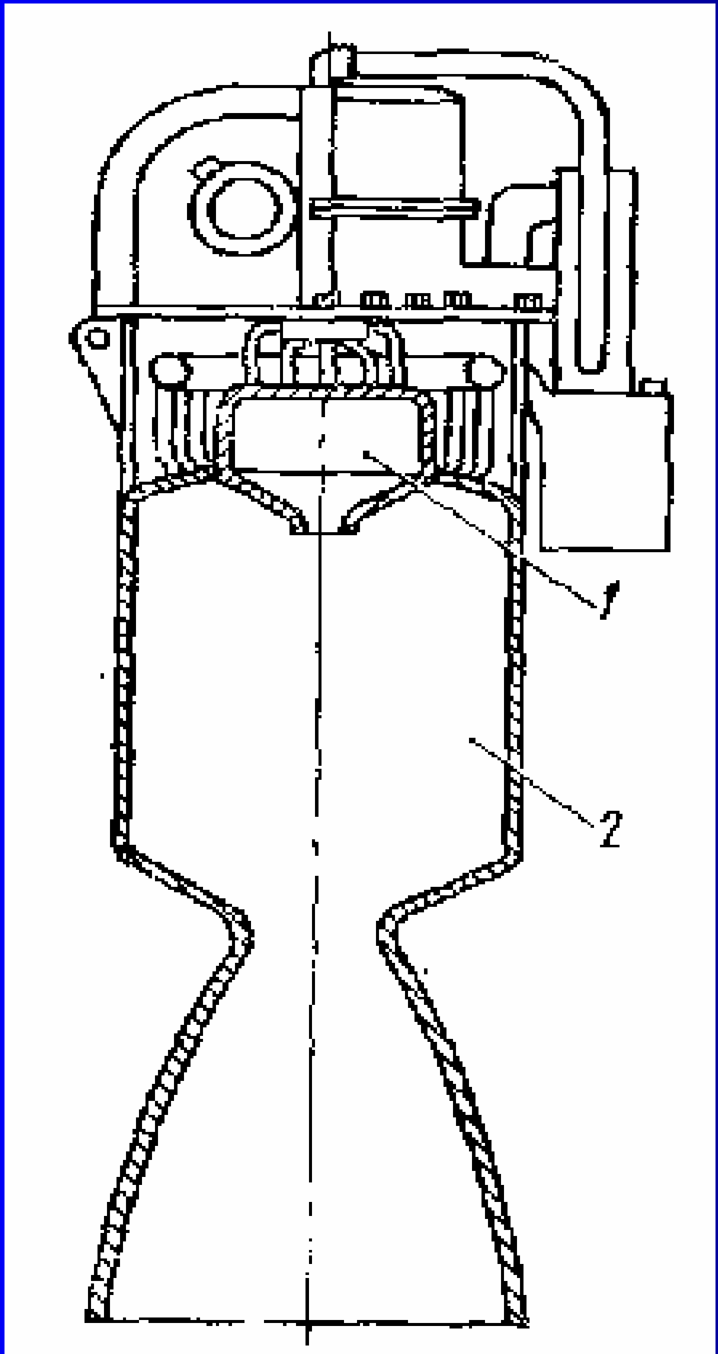
MONOPROPELLANT THRUSTERS



1 - the filter;
2 - a sleeve;
3 - the chamber;
4 - an injector;
5 - fine-grained catalyst;
6, 10 grid;
7 - catalyst;
8 - a nozzle;
9 - a lattice

A construction of a rocket engine on liquid monopropellant (a hydrazine) for a propulsion system of correction of a space vehicle "Mariner"

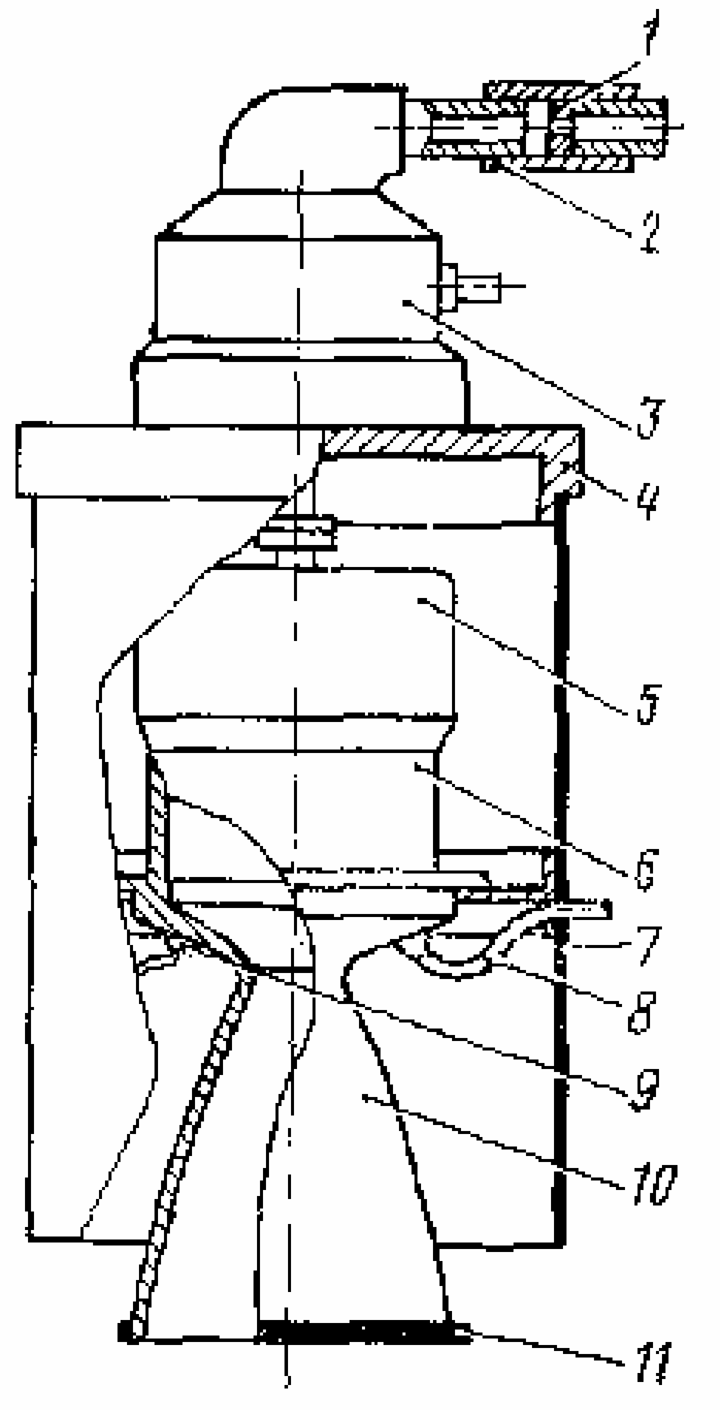
MONOPROPELLANT THRUSTERS



1 - a prechamber;
2 - the main chamber

A construction of a thruster with thermocatalyst decomposition of a hydrazine

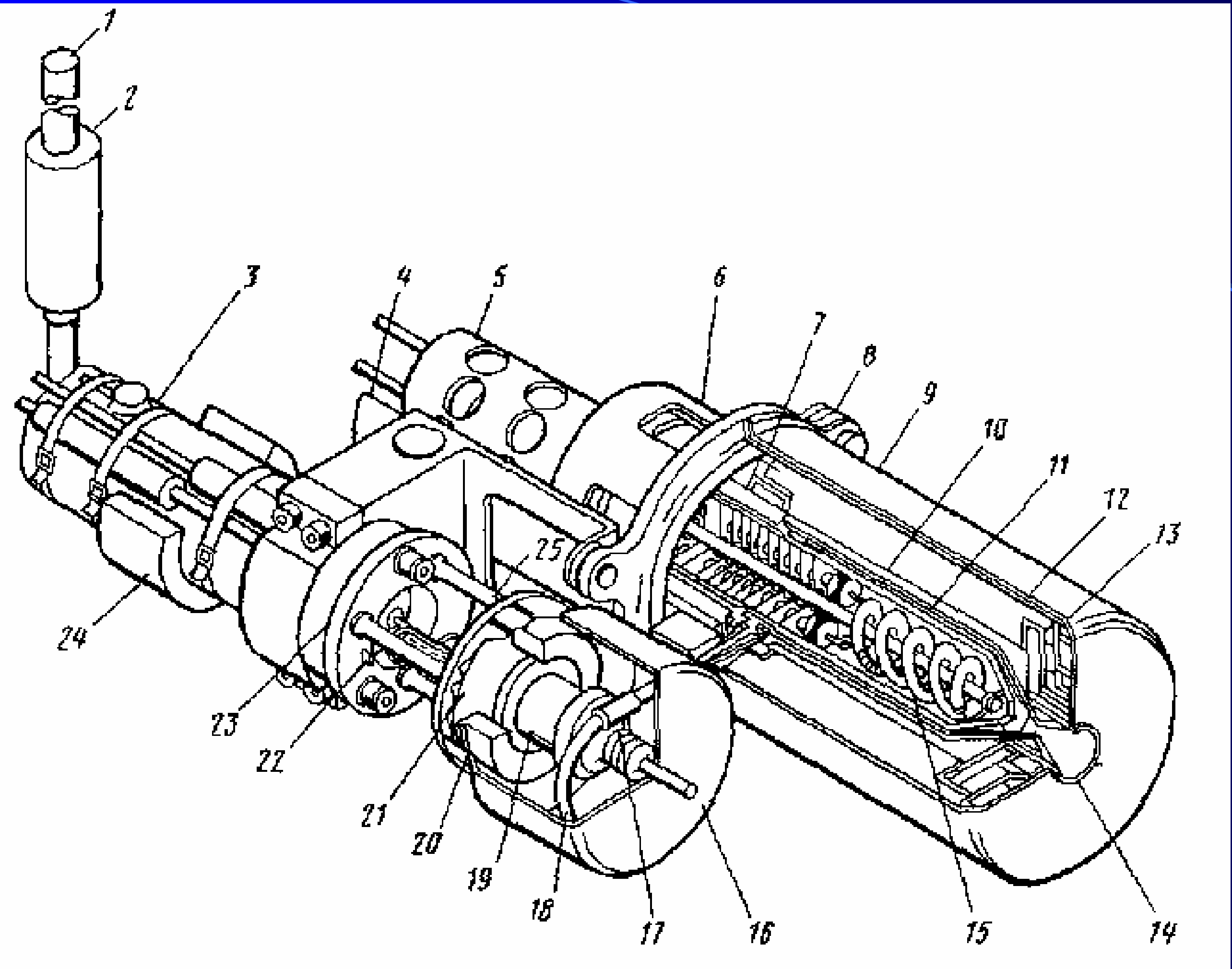
MONOPROPELLANT THRUSTERS



1-constricting spacer;
2-soldered connection;
3-electric valve;
4-mounting flange;
5-an injector;
6-chamber of decomposition with catalyst Shell-405;
7-heat blanket;
8-tube of the pressure transducer;
9-thermocouple;
10-nozzle;
11 - a blow-out plug

A construction of engine MR-50A:

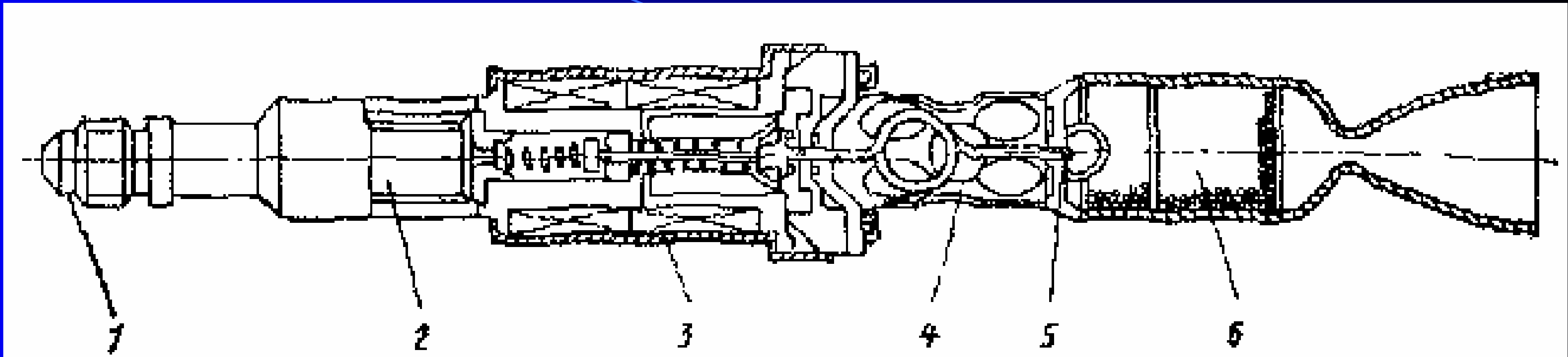
MONOPROPELLANT THRUSTERS



1 - an entrance of a hydrazine;
2 - the jet resistor;
3 - the hydrazine valve;
4 - carrying heat blanket;
5 - an electric heater of products of decomposition;
6 - a load-carrying structure;
7 - a barrier tube;
8 - an assembly design;
9 - a heat blanket;
10 - an external case of the heat exchanger;
11 - an internal case of the heat exchanger;
12 - a radiative screen;
13 - disks of a radiative screen;
14 - a nozzle;
15 - an electro-thermal element;
16 - a heat blanket of the gas
17 - a soldered fitting pipe;
18 - pressure relief pipe;
19 - the chamber of decomposition of the gas generator;
20 - an electric heater of a catalyst package;
21 - an injector;
22 - the thermal shunt;
23 - a fitting of the valve;
24 - an electric heater of the valve;
25 - thermo-insulating baffle fin

A hydrazine thruster with an electroheating of products of decomposition:

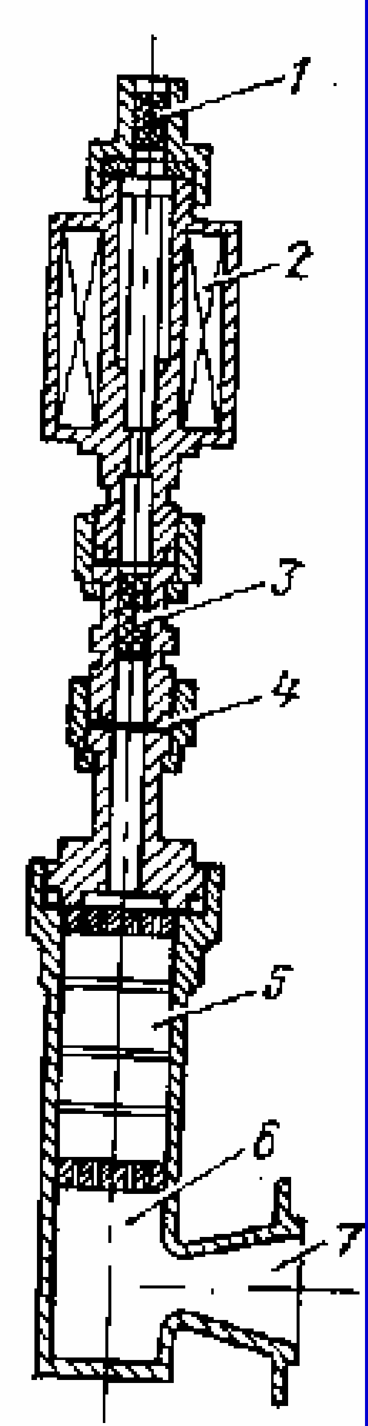
MONOPROPELLANT THRUSTERS



The construction scheme of the hydrazine engine:

1 - a supply of propellant;
2 - the filter,
3 - the valve;
4 - thermal resistance;
5 -an injector;
6 - a catalyst package

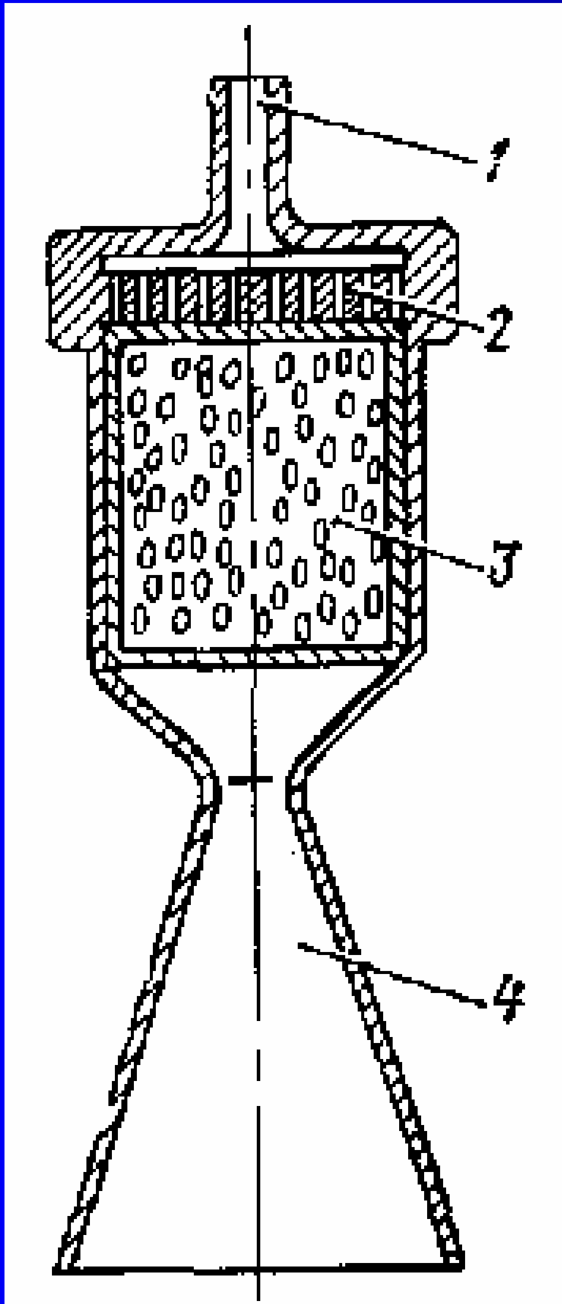
MONOPROPELLANT THRUSTERS



1, 3-filter;
2-solenoidal magnet valve;
4-throttling orifice;
5-catalytic package;
6-chamber;
7-nozzle

A construction of a liquid rocket thruster on hydrogen dioxide with the thrust of 107N for an attitude control system of the american space vehicle "Mercury" :

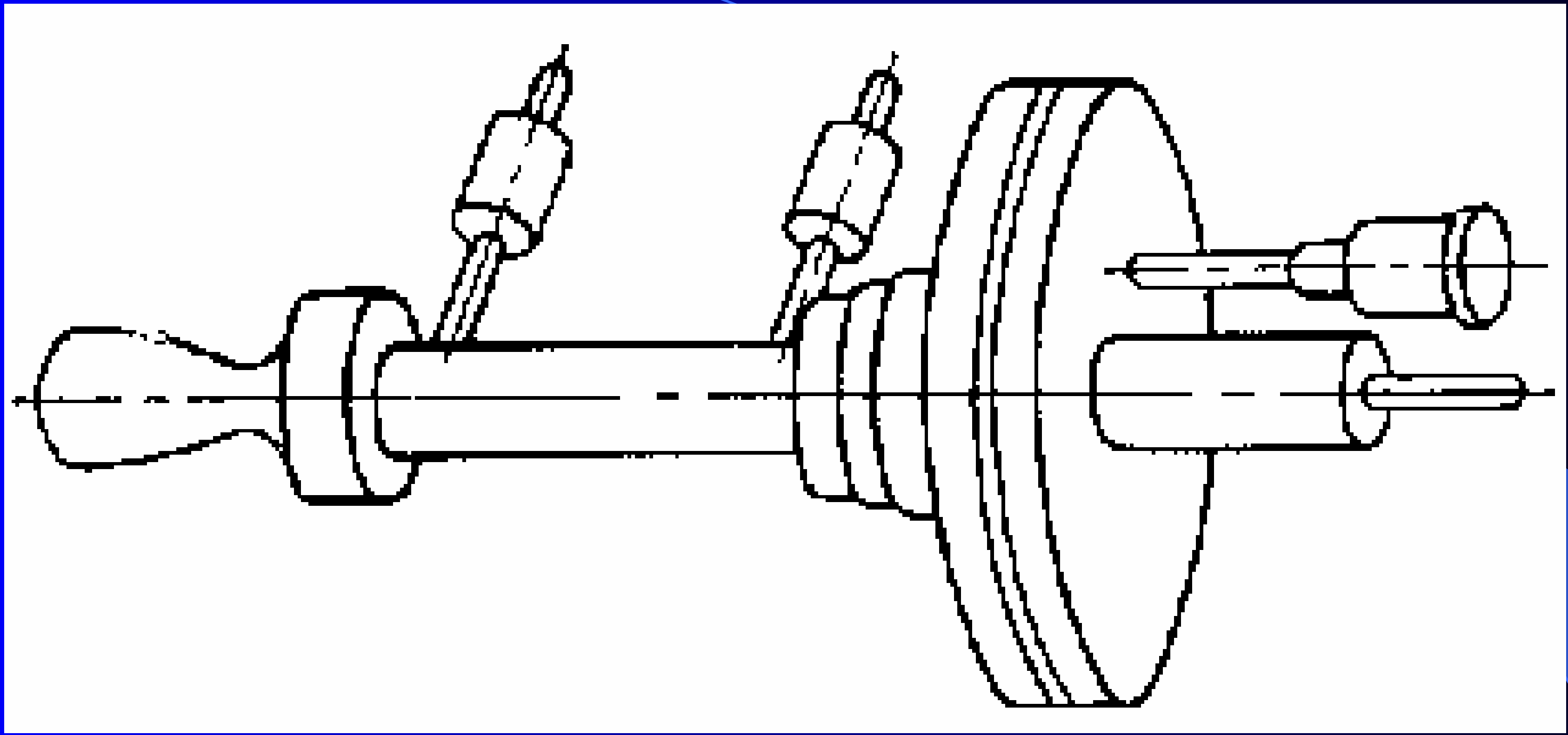
MONOPROPELLANT THRUSTERS



1-supply of propellant;
2-spray device;
3-catalyst;
4-nozzle

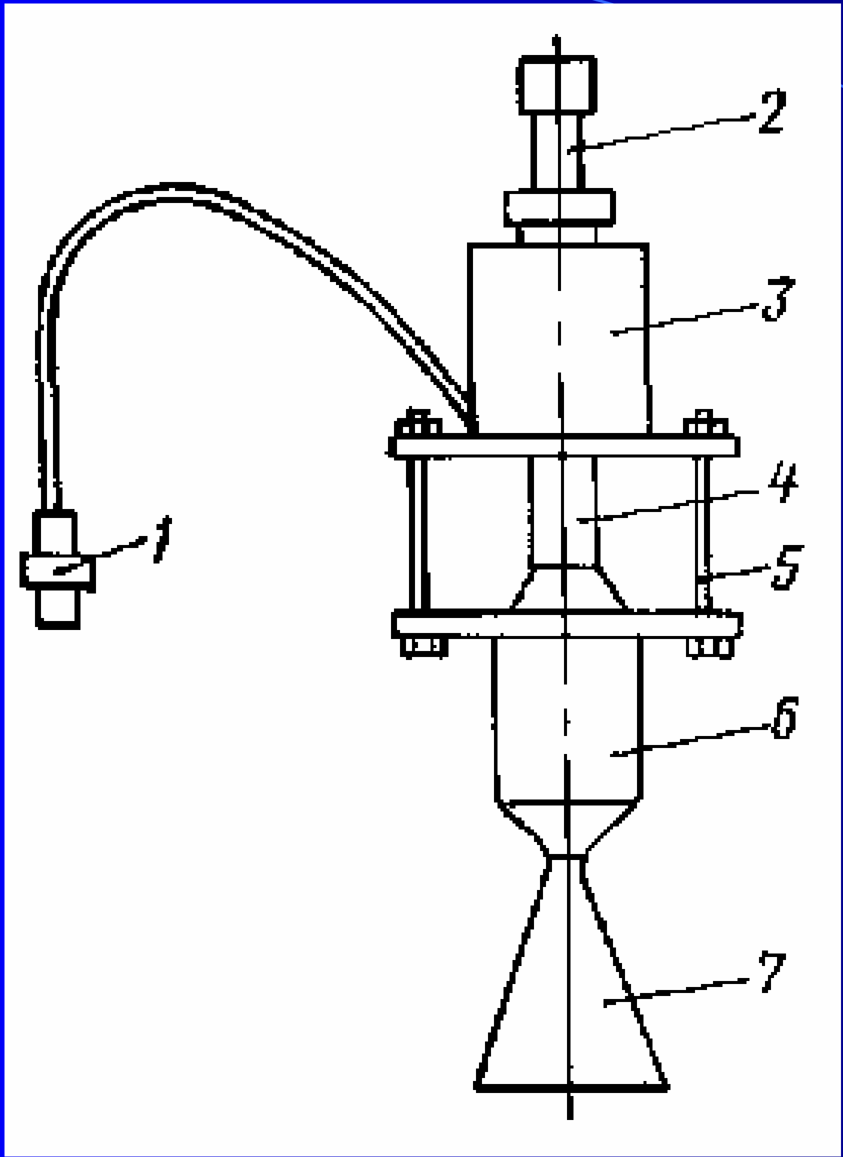
A construction of american liquid thruster on hydrogen dioxide of firm "Bell Aerospace" for a space vehicle "Pioneer":

MONOPROPELLANT THRUSTERS



A general view of a liquid rocket thruster on a hydrazine of French association SEP for attitude control systems of satellites

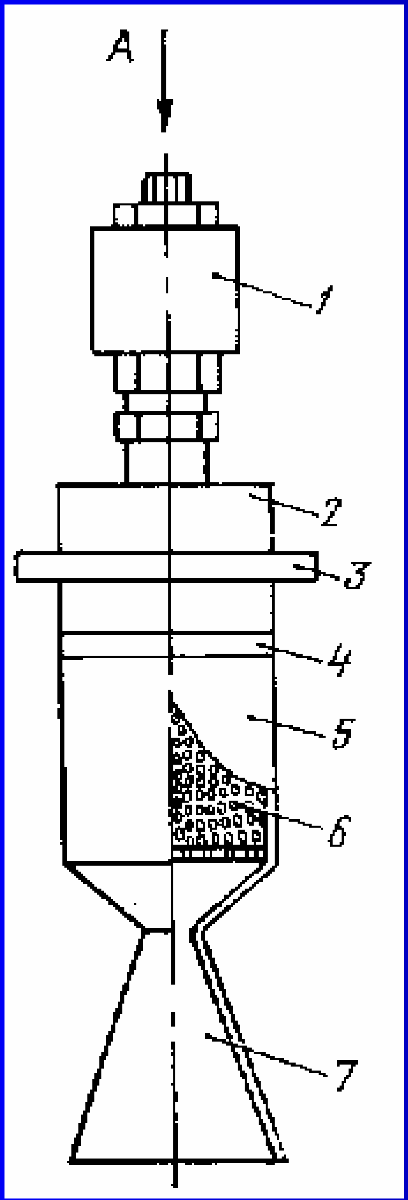
MONOPROPELLANT THRUSTERS



1-plug and socket joint;
2-pipe connection of a supply of propellant;
3-magnet valve;
4-thermostat;
5-mounting point of the chamber to the valve;
6 - the chamber;
7-nozzle

A construction of the engine - K13D of firm Markvardt of thrust 22; 6 N, working on a hydrazine:

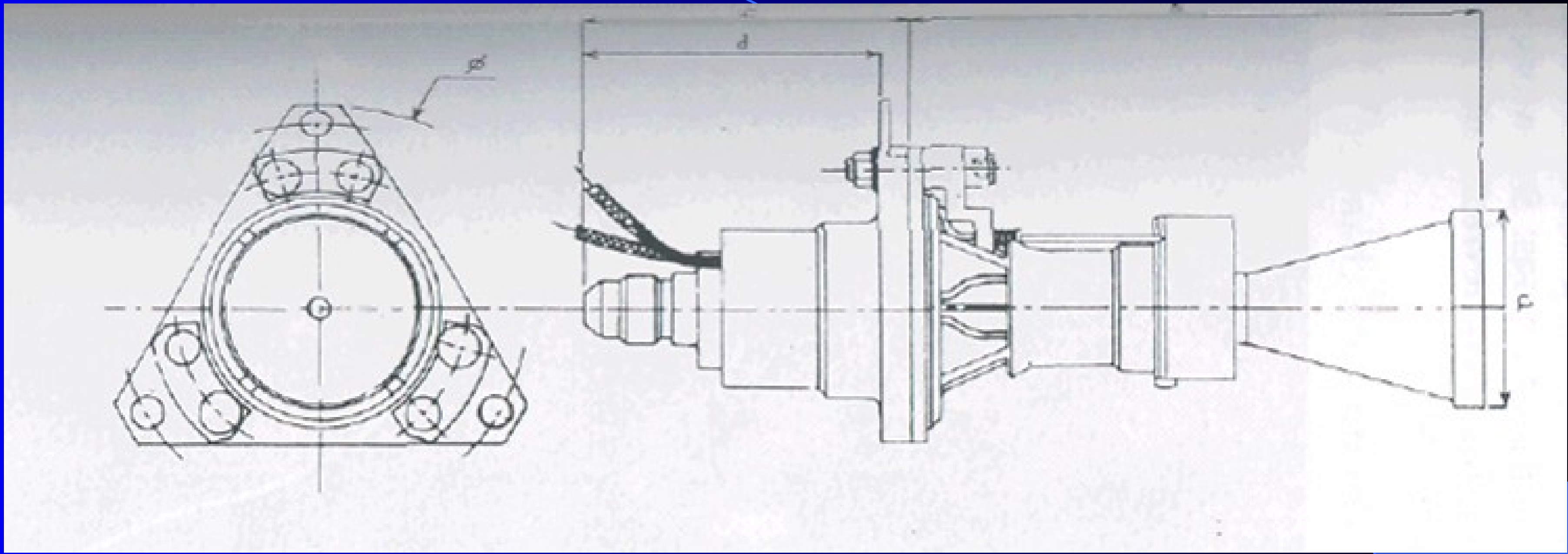
MONOPROPELLANT THRUSTERS



1-pulse electro valve;
2-thermal resistance;
3-flange of attachment;
4-injector;
5-chamber of decomposition;
6-catalyst;
7-nozzle of a supply of a hydrazine

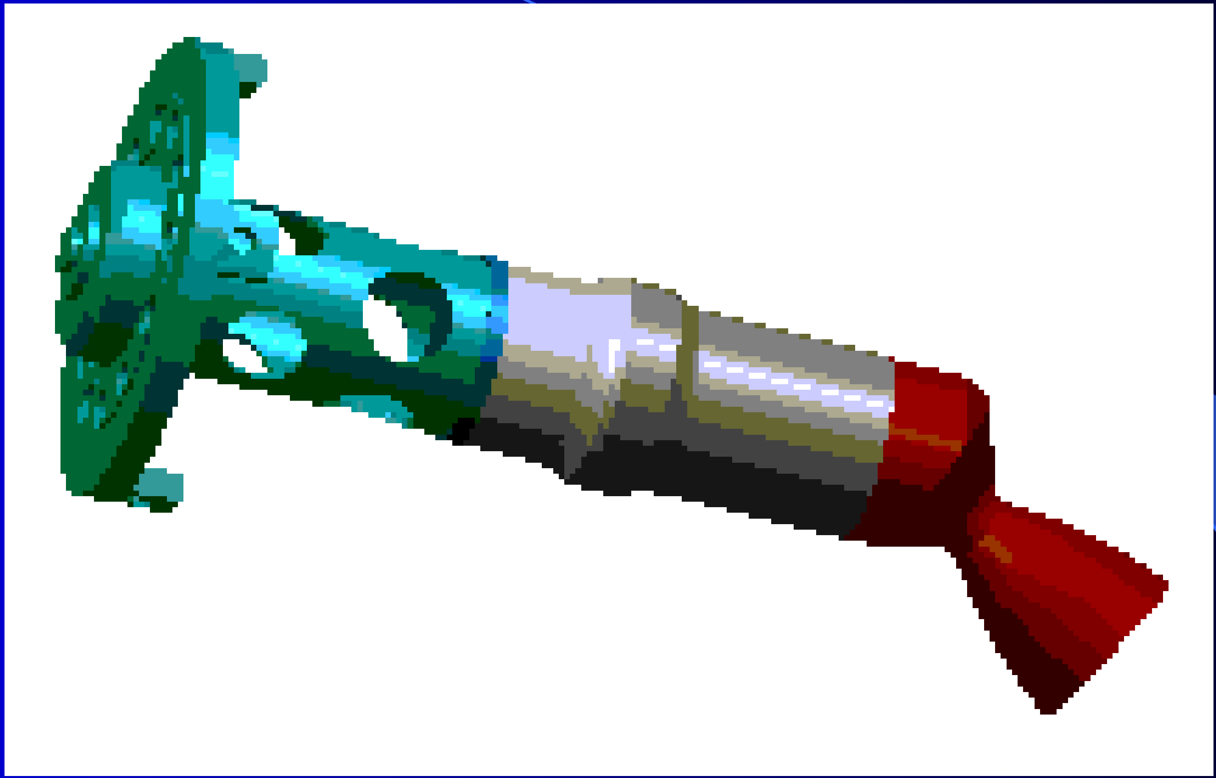
A general view of a liquid thruster of firm Belkoff (Germany) on a hydrazine of thrust 14,7 N:

MONOPROPELLANT THRUSTERS



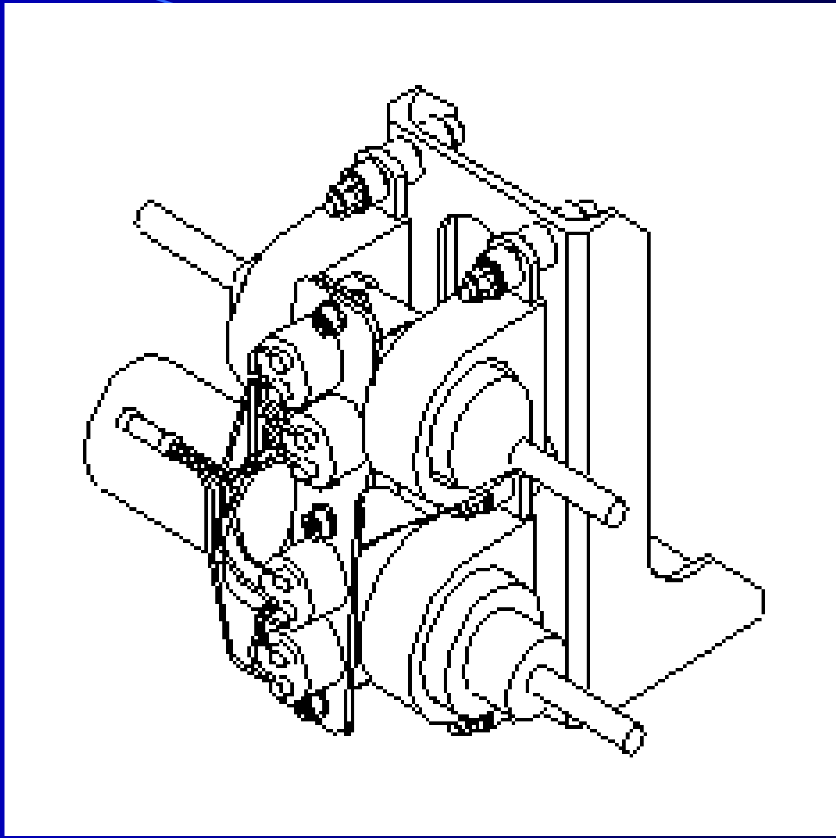
3 - 15 N Class SEP hydrazine propulsion systems

MONOPROPELLANT LIQUID JET SYSTEMS



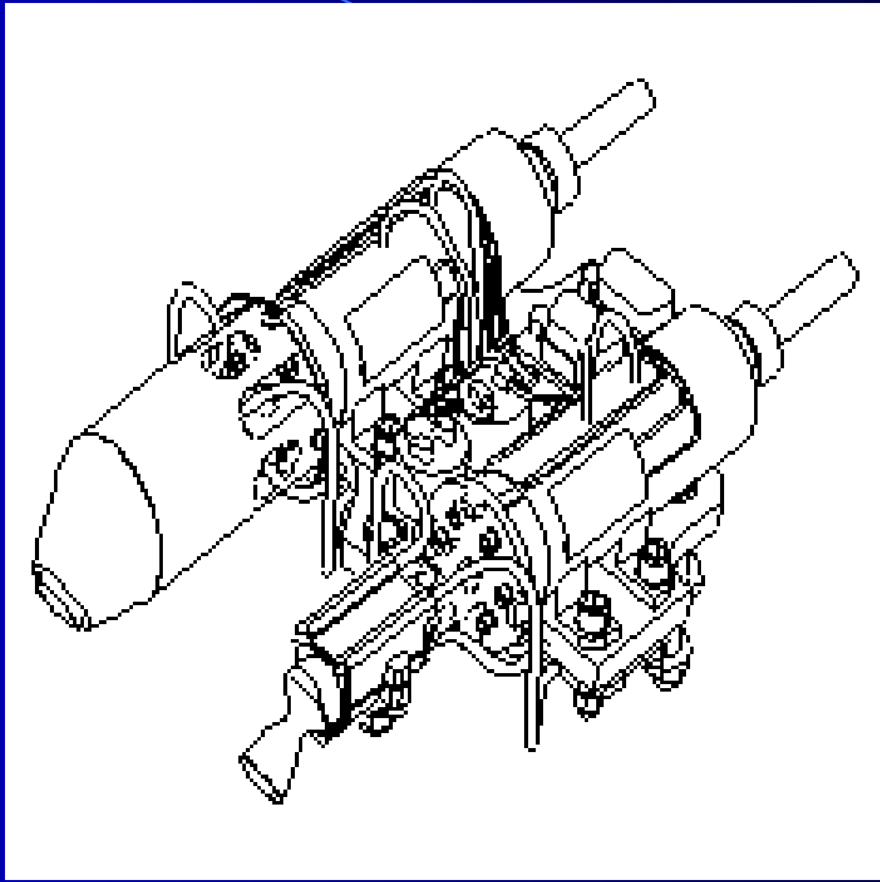
Configuration of 4.45N MRE-1 thruster

MONOPROPELLANT LIQUID JET SYSTEMS



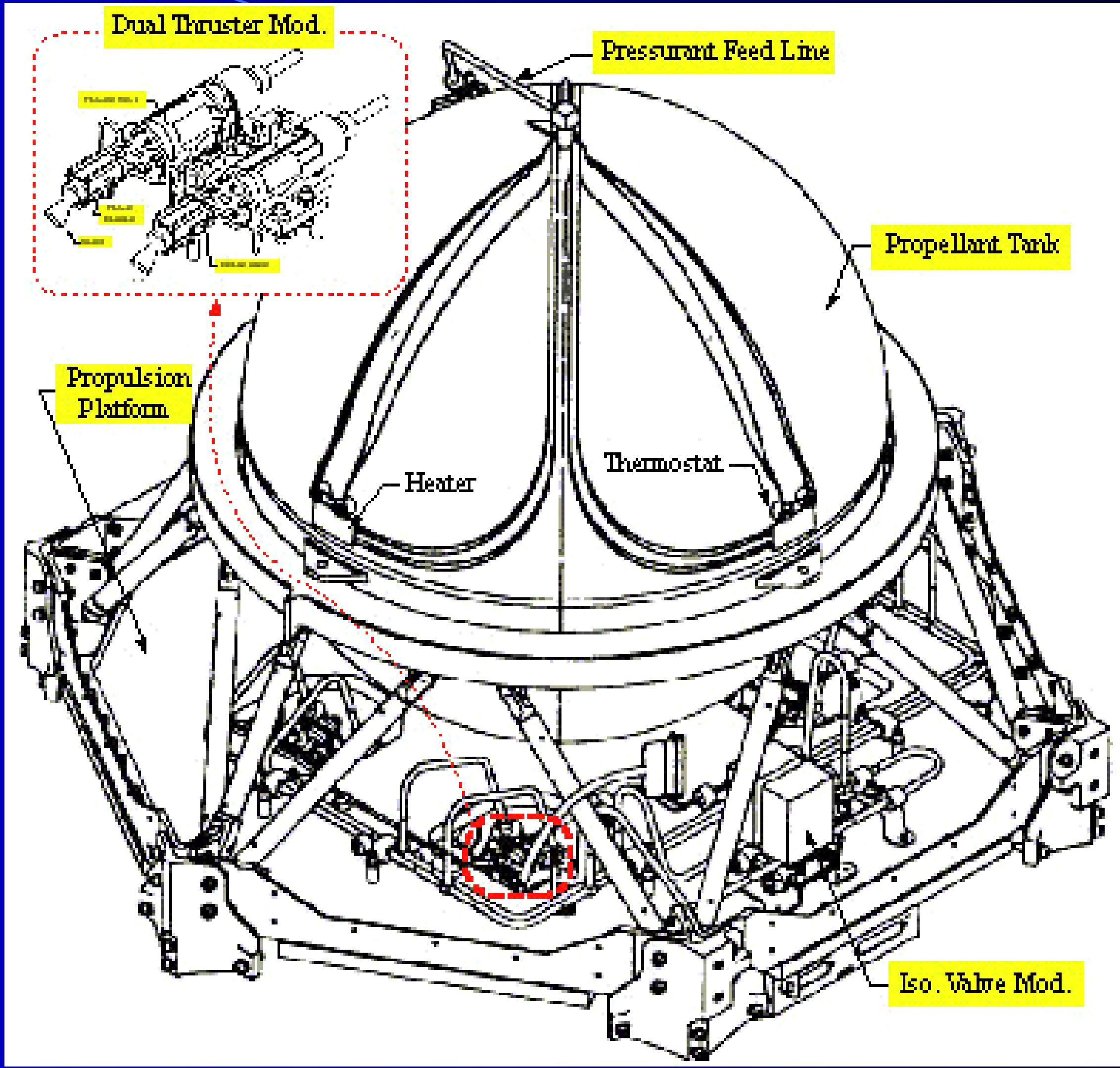
Filter/pressure transducer module

MONOPROPELLANT LIQUID JET SYSTEMS



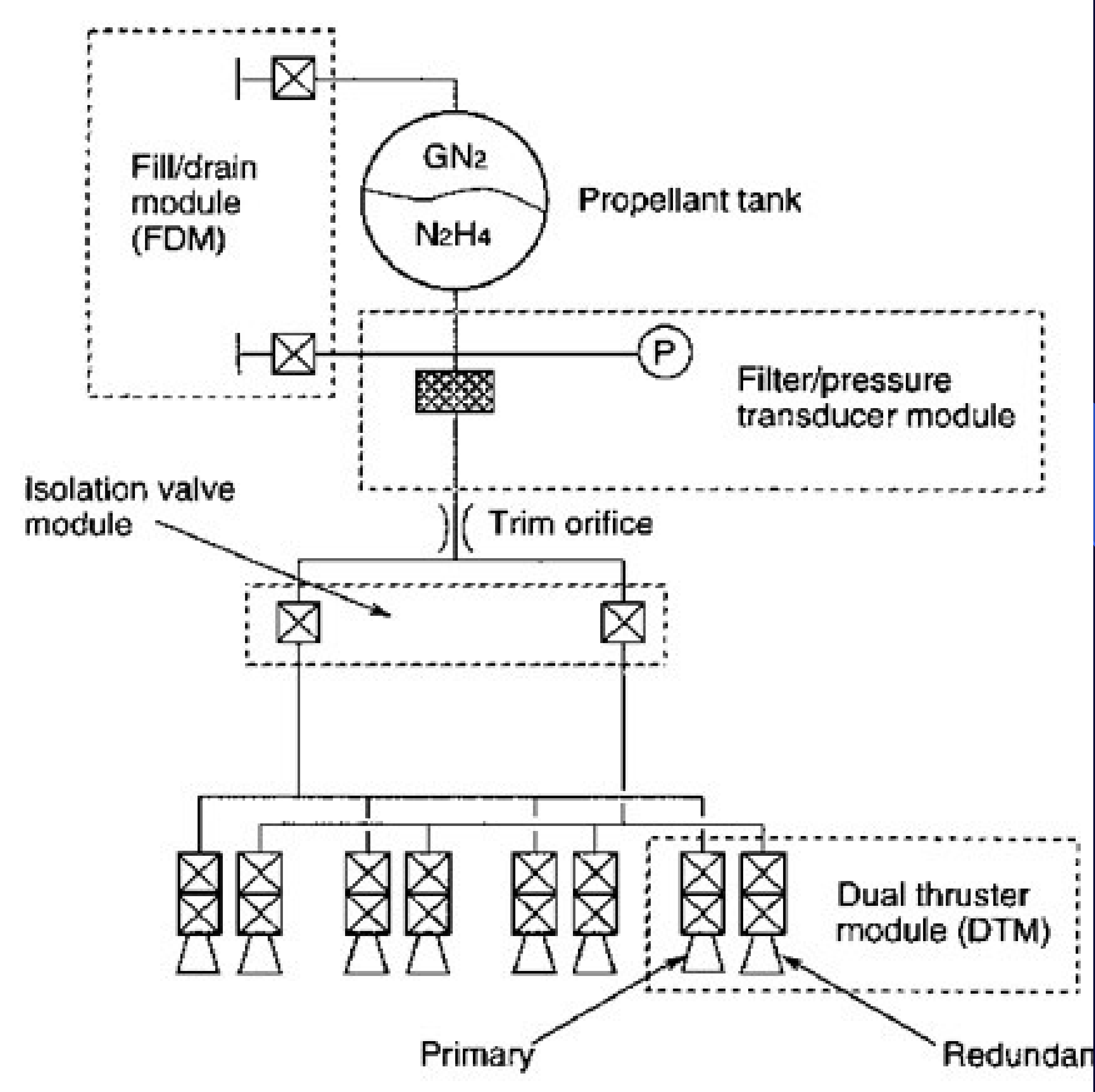
Dual thruster module

MONOPROPELLANT LIQUID JET SYSTEMS



Configuration of KOMPSAT-1 propulsion system

MONOPROPELLANT LIQUID JET SYSTEMS



BIPROPELLANT LIQUID JET SYSTEMS

Jet systems with use as a propulsive mass of products of combustion of liquid bipropellant have received now most wide spread occurrence.

It means:

High energetics of thrusters;

Good dynamic properties;

Small consumption of energy;

Small weight;

Small sizes;

Large service life.

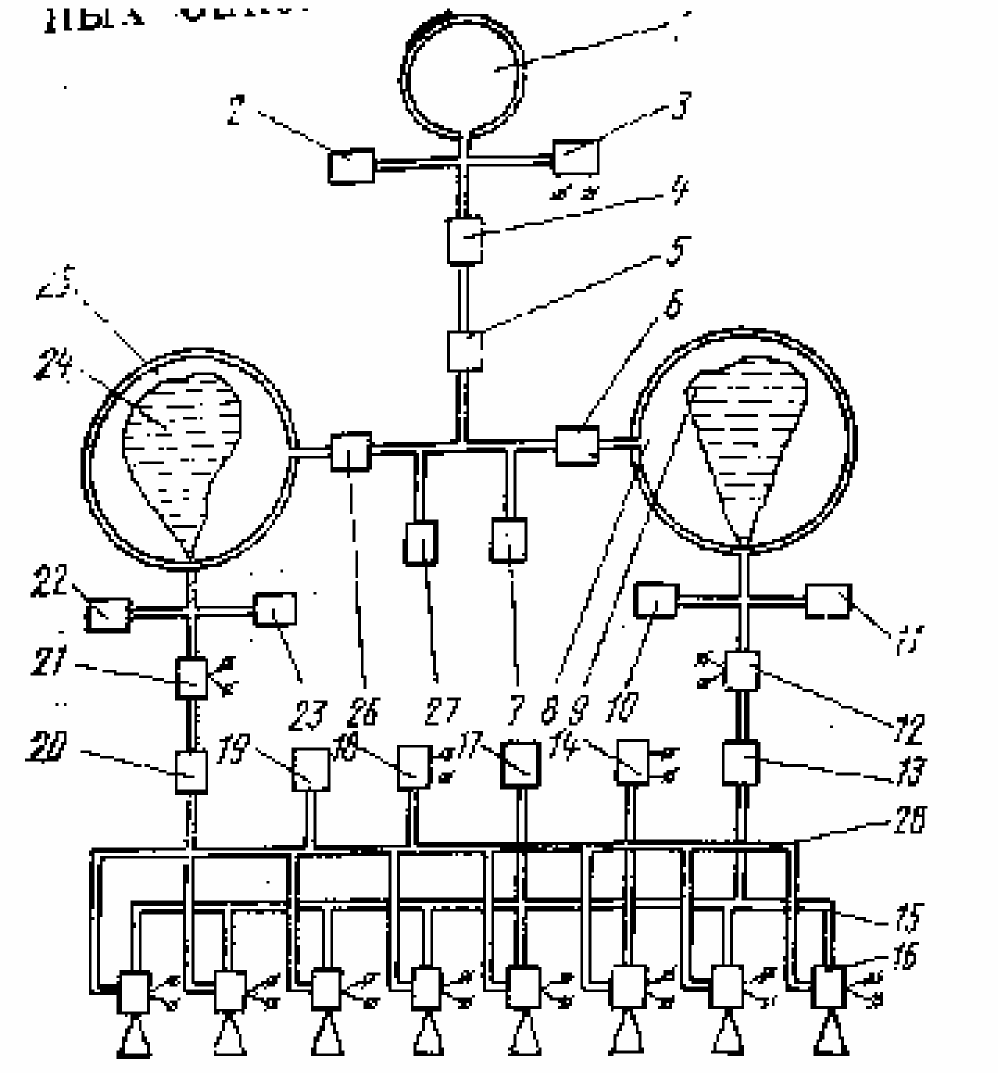
The top level of thrust of engines practically is not limited.

BIPROPELLANT LIQUID JET SYSTEMS

Properties of some fuels and oxidizers

Characteristics of components	Nitrogen tetroxide N_2O_4	Hydrazine N_2H_4	Monomethyl hydrazine $CH_3N_2H_3$	Dimethyl hydrazine $(CH_3)_2N_2H_2$	Aerozin - 50; 50% N_2H_4 50 % $(CH_3)_2N_2H_2$
Density at temperature 25°C, g / sm^3	1.450	1.064	0.874	0.784	0.899
Freezing temperature, K	261,9	274,7	220,8	215,9	265,7
Boiling point, K	294,3	386,7	360,7	336,1	343
Molecular weight	92,016	32,048	46,075	60,102	45,584
Evaporation heat, kJ/kg	415	13335	877	583	-
Theoretical specific impulse (with N_2O_4), m/s	-	3480	-	3310	3070
Temperature of products of combustion in the chamber, K	-	3247	-	3415	3353
Mass components ratio	-	1,33	-	2,57	2,25

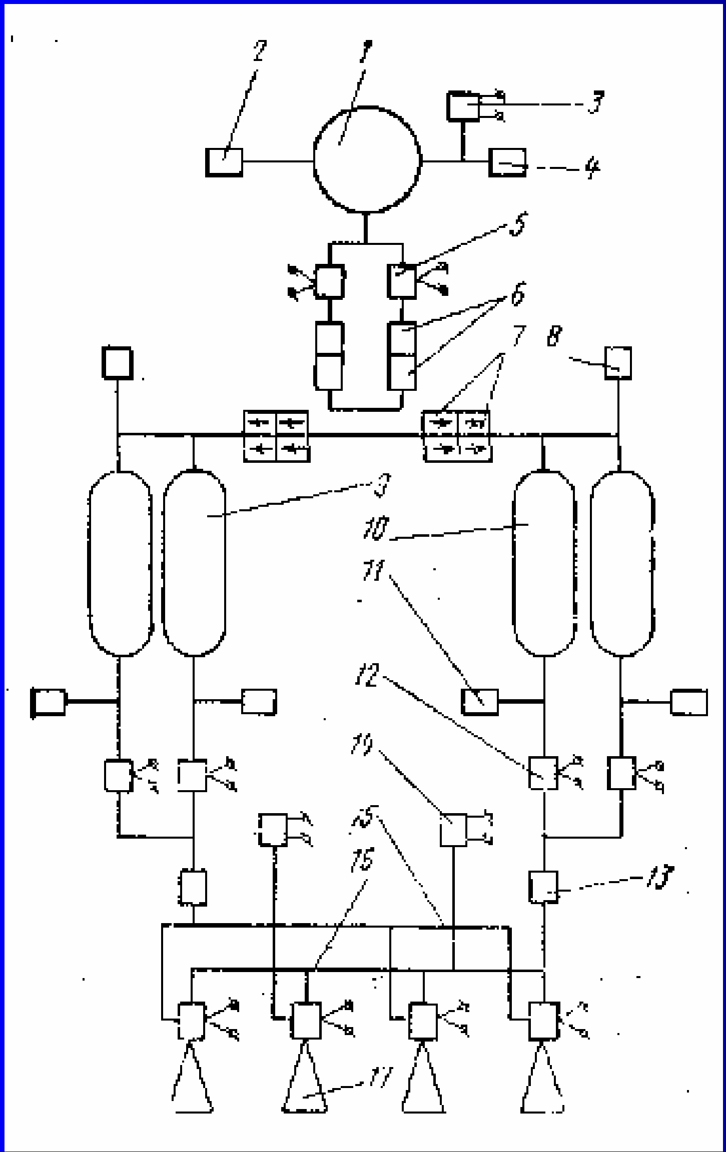
BIPROPELLANT LIQUID JET SYSTEMS



1-bottle with pressure gas;
2-refuelling valve;
3-pressure transducer;
4-start valve of pressurization;
5-pressure regulator;
6, 26-reverse valves;
7, 17, 19-verifying valves;
8-fuel tank;
9, 24-expulsive bags;
10, 23, 27-relief valves;
11, 22 - filling-draining valves;
12, 21-cut-off fuel valves;
13, 20-fuel filters;
15, 28-collectors;
16-thruster;
25-oxidizier tank

Fig. 3.34. The principal diagram of a jet control system on liquid bipropellant

3.6. BIPROPELLANT LIQUID JET SYSTEMS



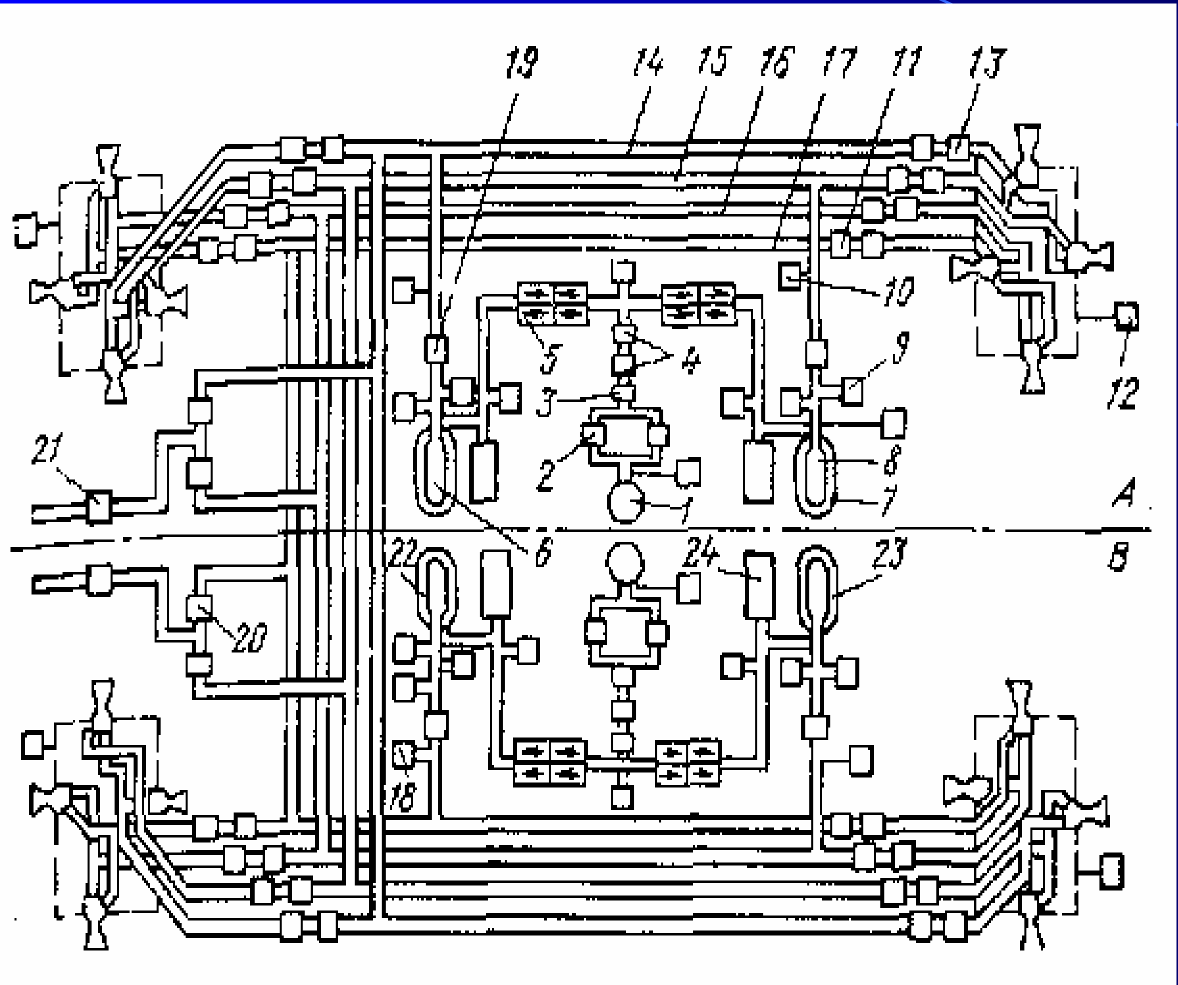
1-bottle with helium;
2-charging valve;
3-pressure transducer of gas;
4-relief valve;
5 - cut-off valve;
6-unit of pressure regulators;
7-unit of reverse valves;
8 - the relief valve;
9-fuel tanks;
10-oxidizier tanks;
11-filling-draining fuel valves;
12-fuel valves;
13-filters;
14-pressure transducers of propellant;
15-collector of a fuel;
16-collector of an oxidizer;
17-engine

Fig. 3.35. A functional diagram of a jet control system of a service compartment of the spacecraft "Apollo".

BIPROPELLANT LIQUID JET SYSTEMS

The jet control system of a lunar compartment is installed on its ascent stage and is used for following purposes:
- Separations of a lunar compartment from the spacecraft "Apollo",
- Orientations and stabilization of a lunar compartment during self-flight;
- Maneuverings a lunar compartment above a surface of moon before landing;
- Maintenance of a meeting and a docking with the spacecraft "Apollo" after take-off from moon;
- Maintenance of necessary incremental velocity if the ascent engine will be disconnected earlier than estimated time.

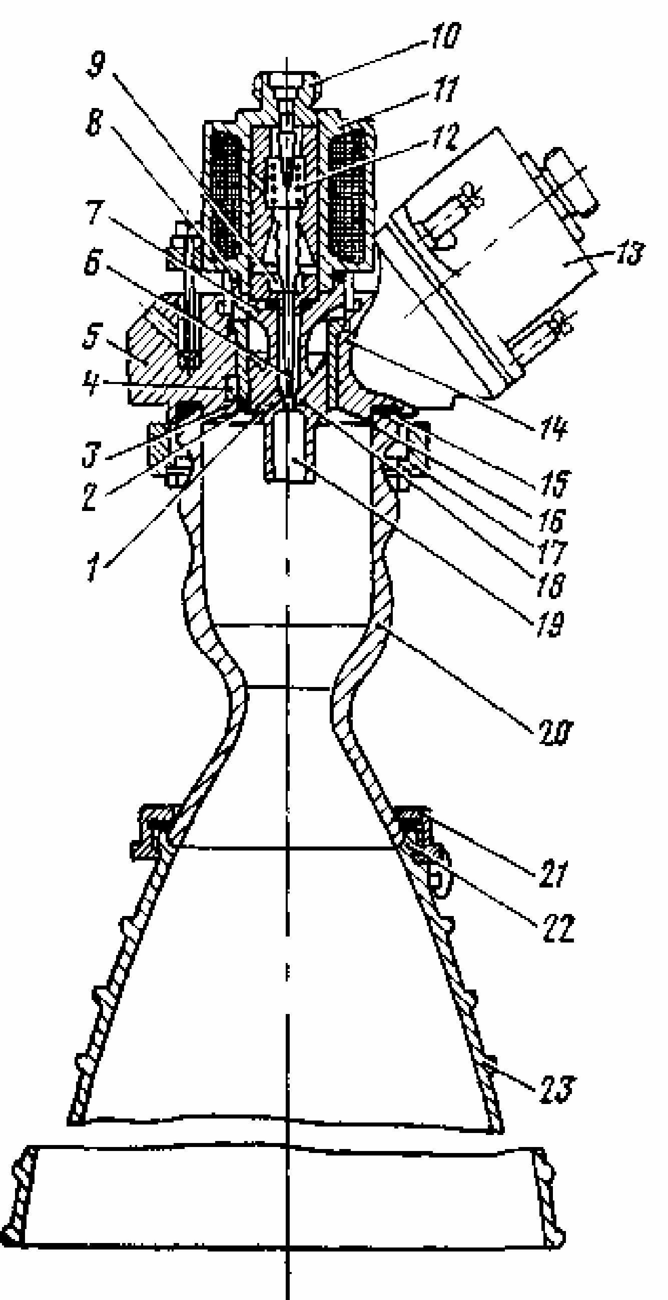
BIPROPELLANT LIQUID JET SYSTEMS



1-bottle with the compressed helium;
2-start valve;
3-filter;
4 - pressure regulators;
5-unit of reverse valves;
6-oxidizier tank of a system A;
7-fuel tank of a system A;
8-teflon bag;
9-filling-draining gate;
10-pressure transducer;
11-cut-off valve;
12-temperature detector;
13-filter;
14-oxidizer line of a system A;
15-main of a fuel of a system A;
16-oxidizer line of a system B;
17-main of a fuel of a system B;
18-pressure transducer;
19-main cut-off valve;
20-valves of fuel supply from tanks of the main engine;
21-transfer valve;
22-fuel tank of a system B;
23-oxidizier tank of a system B;
24 - the relief valve

Fig. 3. 36 Functional diagram of a jet control system of a lunar compartment (a system A and B):

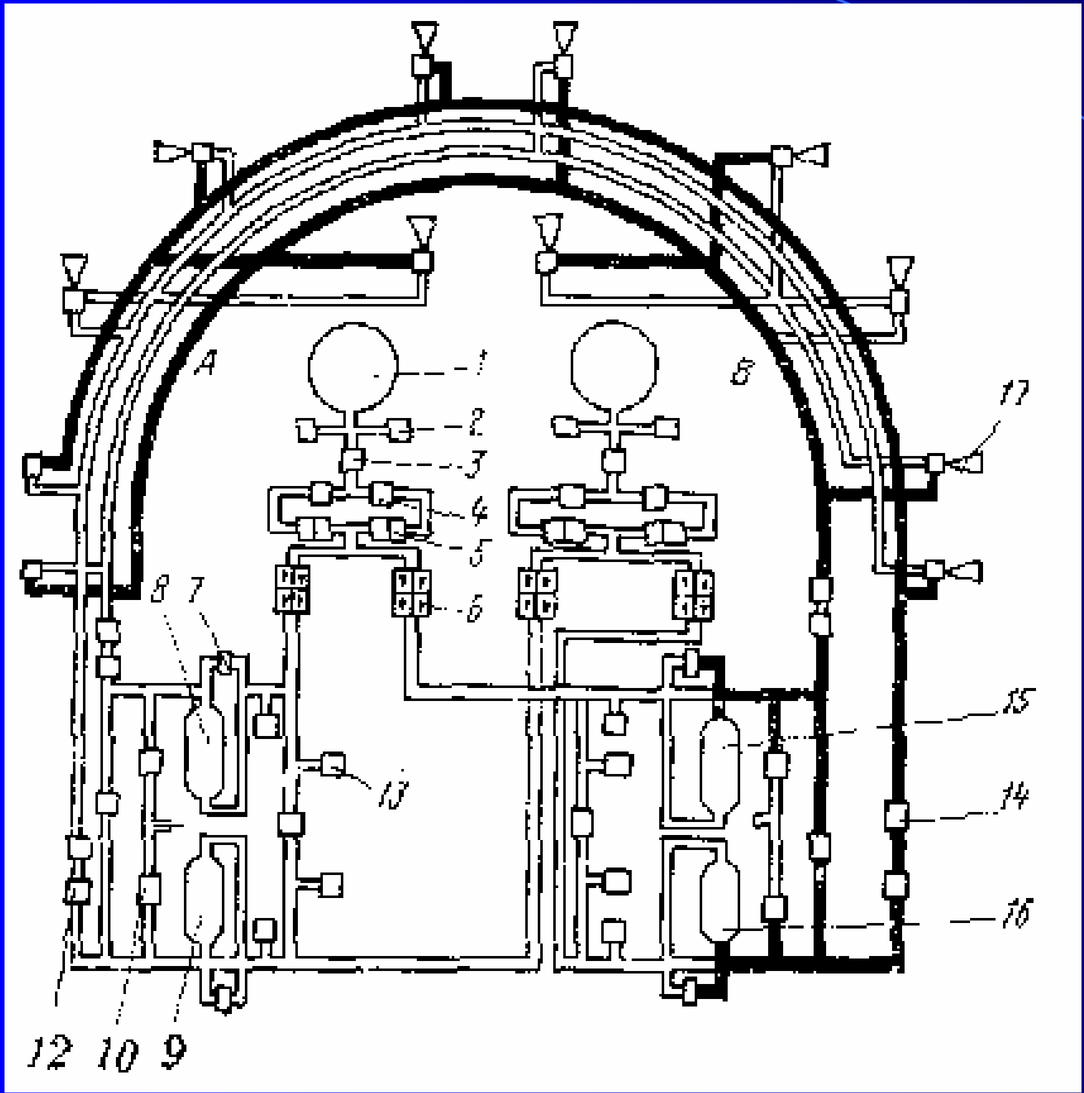
BIPROPELLANT LIQUID JET SYSTEMS



1-eight apertures of an oxidizer;
2-eight main injectors of a fuel;
3-eight injectors of a fuel for cooling;
4-collector of a fuel;
5-head;
6-supply of an oxidizer;
7-inserts;
8-isolator;
9-saddle;
10-valve of an oxidizer;
11-magnet coil;
12-spring;
13-valve of a fuel;
14-supply of a fuel;
15-seal;
16-eight injectors for cooling of the prechamber;
17-ring;
18-aperture of an oxidizer;
19-prechamber;
20-chamber;
21-ring;
22-nozzle;
23-socket

Fig. 3. 36a. A construction of engine of R-4D:

BIPROPELLANT LIQUID JET SYSTEMS



1 - bottles with the compressed helium;
2 - the charging valve;
3 - start valve of helium;
4 - cut-off valves of helium;
5 - pressure regulators;
6 - the unit of reverse valves;
7 - a transfer valve;
8 - the fuel tank of a system A;
9 - the fuel tank of a system B;
10 - overflow valves;
12 - a blowout diaphragm and the filter;
13 - by-pass relief valves;
14 - fuel cut-off valves;
15 - the oxidizer tank of a system A;
16 - the oxidizer tank of a system B;
17 - engines

Fig. 3.37. A functional diagram of a jet control system of a compartment of spacecraft crew of "Apollo" (systems A and B)

3.6. BIPROPELLANT LIQUID JET SYSTEMS

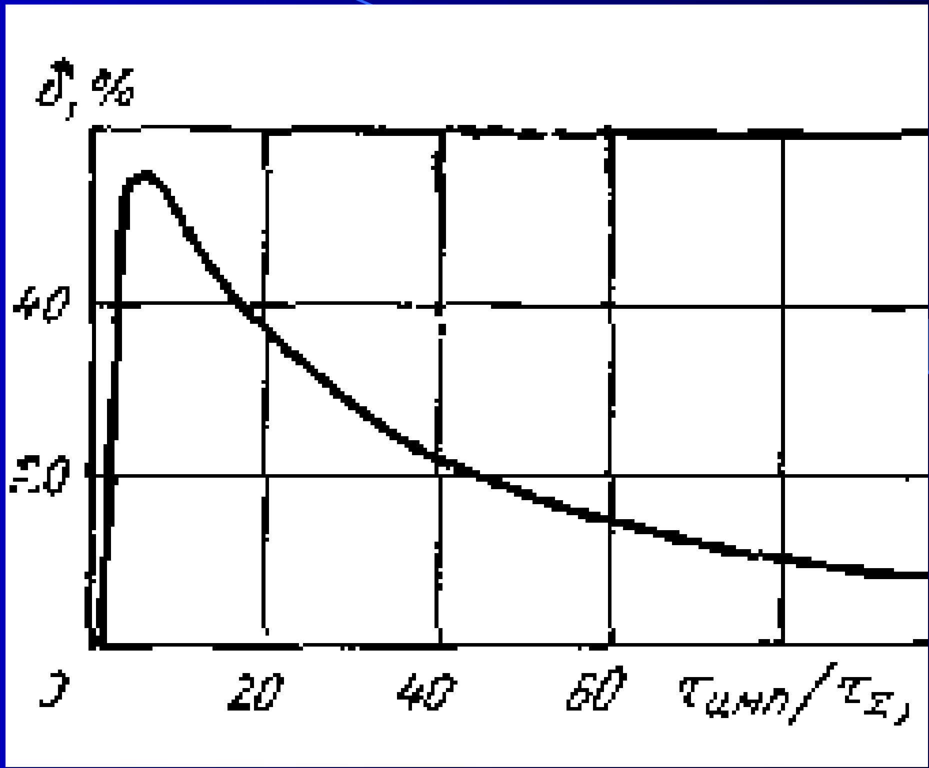
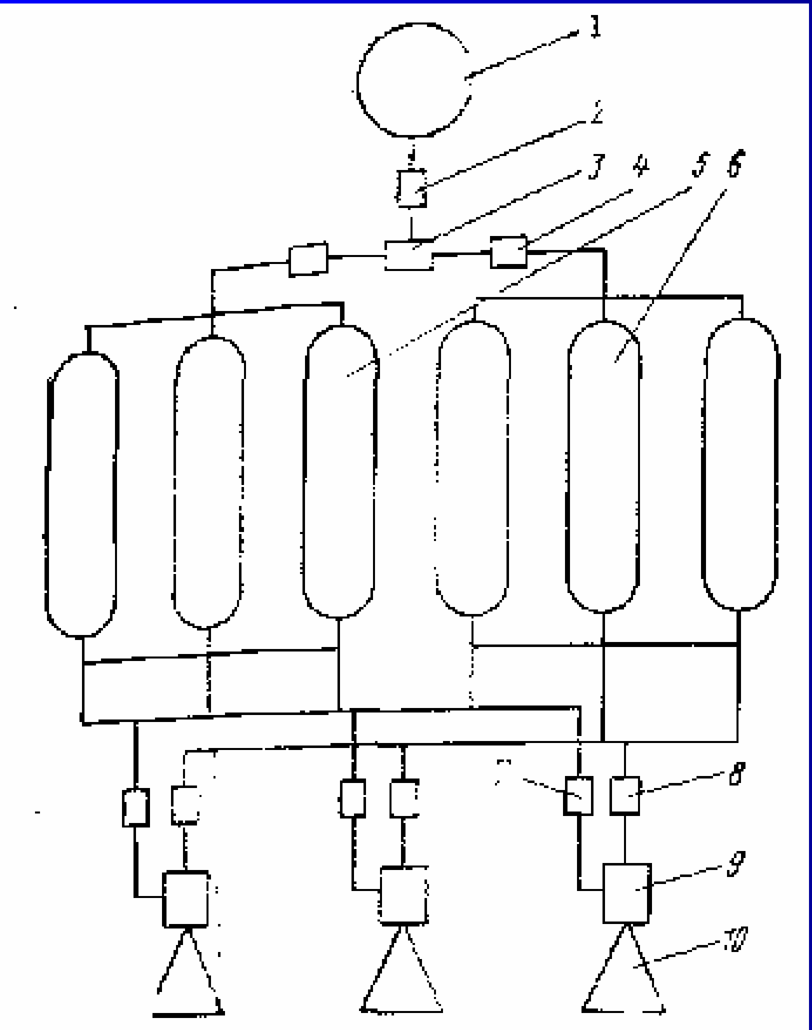


Fig. 3. 38. Dependence of relative thickness of the ablative insert of engine SE-8 on operational mode

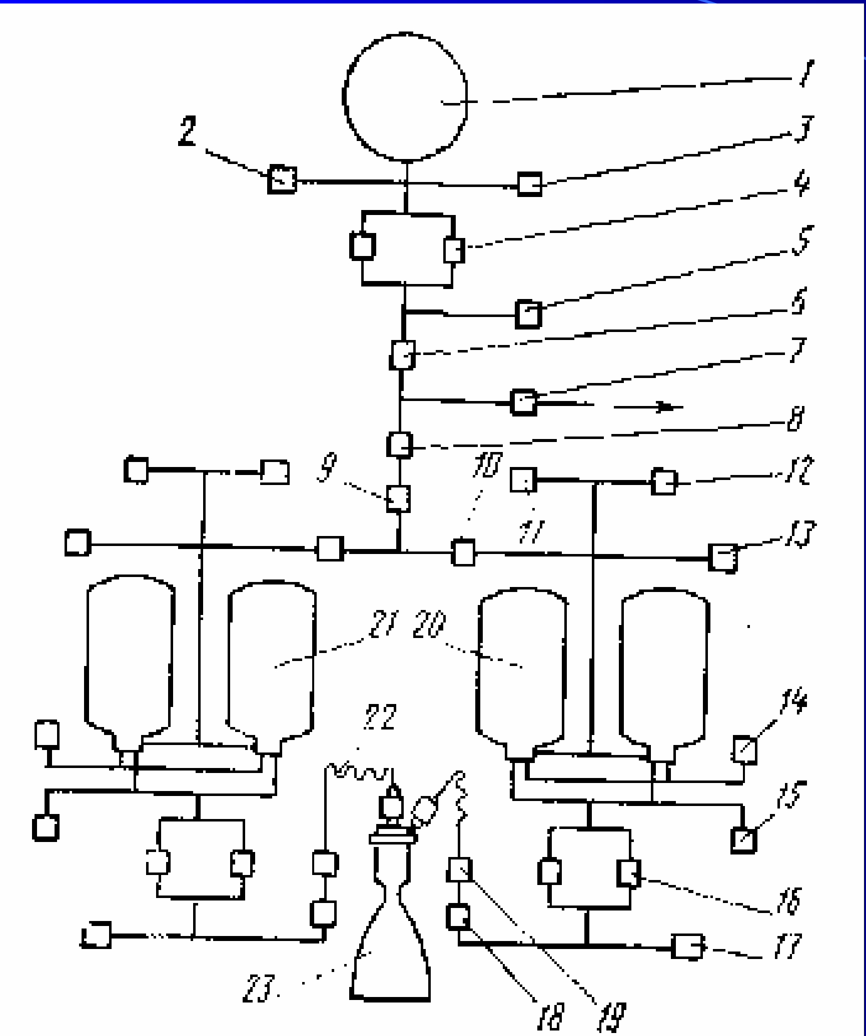
BIPROPELLANT LIQUID JET SYSTEMS



1 - a bottle with helium;
2 - start valve;
3 - the pressure regulator;
4 - by-pass valves;
5 - tanks with a fuel;
6 - tanks with an oxidizer;
7 - the fuel valve;
8 - the valve of an oxidizer;
9 - the chamber;
10 - a nozzle

Fig. 3. 39. A functional diagram of a jet control system of a space vehicle "Surveyor":

BIPROPELLANT LIQUID JET SYSTEMS



1 - a bottle with the compressed nitrogen;
2 - the charging valve;
3, 12 - pressure transducers;
4 - a starting pyrovalve;
5, 13, 14, 17 - verifying valves;
6 - the filter;
7 - the pressure regulator for engines on the compressed nitrogen p =0.13 MN/m2;
8 - cut-off valve;
9 - the pressure regulator p=1.3 MN/m2;
10 - reverse valves;
11 - the relief valve;
15 - the filling-draining valve;
16 - fuel pyrovalves;
18 - the fuel filter;
19 - a metering jet;
20 - fuel tanks;
21 - oxidizer tanks;
22 - flexible fuel hose pipes;
23 - the engine

Fig. 3. 40. A functional diagram of a jet control system of velocity vector of a space vehicle "Lunar Orbiter":

BIPROPELLANT LIQUID JET SYSTEMS

Injection into the engine chamber is supposed at a gaseous state, due to the fact that during the injection of liquid hydrogen and oxygen at small mass flow rate the significant part of it is in a vaporous state. It causes exclusive instability, due to the biphase injection.

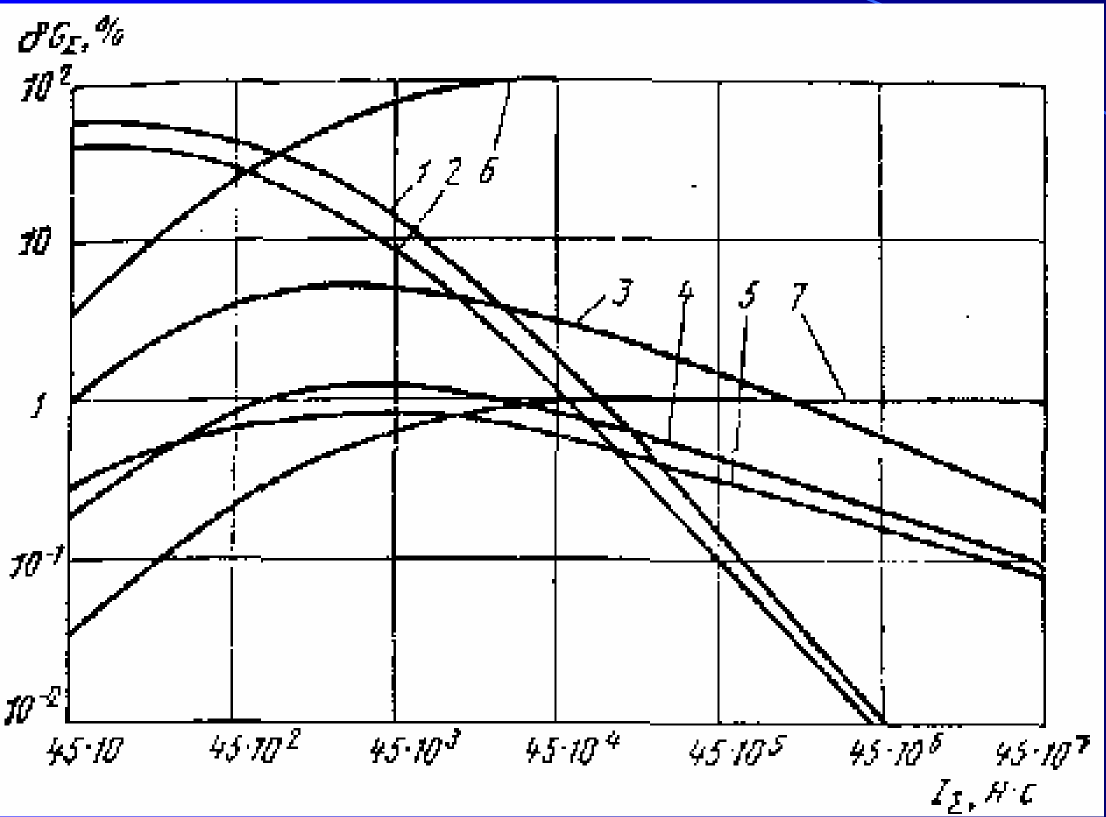
Injection of gaseous oxyhydrogen propellant into the engine chamber leads to significant complication of a system, because of the reason that for gasification of liquid fuel, such additional devices as gas generators, heat exchangers, accumulators etc are required.

3.6. BIPROPELLANT LIQUID JET SYSTEMS

Firms "Markvardt" and "Alice Chalmers" have developed a system, consisting of the installation of an electrolytic cell for obtaining gaseous hydrogen and oxygen by the electrochemical decomposition of a water, which is stored onboard of a flight vehicle as a fuel.

Energy consumption of units makes ~7V, and as a source of it the general solar batteries can be used. Thrust of a propulsion system is 4.5 N, at a specific impulse of 3320 m/s.

3.6. BIPROPELLANT LIQUID JET SYSTEMS



1 - thrusters;
2 - controls unit and pipelines;
3 - tanks;
4 - elastic dividers;
5 - bottles;
6 - propellant;
7 - a pressurant gas

Fig. 3. 41. Dependence of consistents of full weights of a system on bipropellant N_2O_4+A-50 on an integral impulse of thrust at two thrusters R = 225 N, (p_c=0,35 MN/m², the combustion chamber is with radiation cooling, gas pressurization of N_2 is stored in bottles from titanium alloy p_b=31 MN/m²):

BIPROPELLANT LIQUID JET SYSTEMS

Characteristics of substantial liquid-jet systems on bipropellant on the basis of a hydrazine fuel and nitric oxides are as following:

Thrust is 4.5 - 10000 N;

Specific impulse at continuous operation is 2600 - 3000 m/s;

Specific impulse at a pulse mode is 1320 - 1420 m/s;

Time of an impulse is 0.01s;

Mass components ratio of propellant is 1.5 - 2.3;

Integral impulse is approximately 2230000 N.s;

Integral operating time is approximately 5760000 s;

Amount of actuations is approximately 10^5;

$\tau_{0,9}$=0,005 - 0,02 s;

$\tau_{0,1}$=0,007 - 0,03 s.

BIPROPELLANT LIQUID JET SYSTEMS

At a large total impulse of thrust, mass characteristics of a system on bipropellant are determined, first of all, by a kind and a propellant budget and by unit strength of a material of tanks and bottles, and also by a design perfection of a system (fig. 3.42 and 3.43).

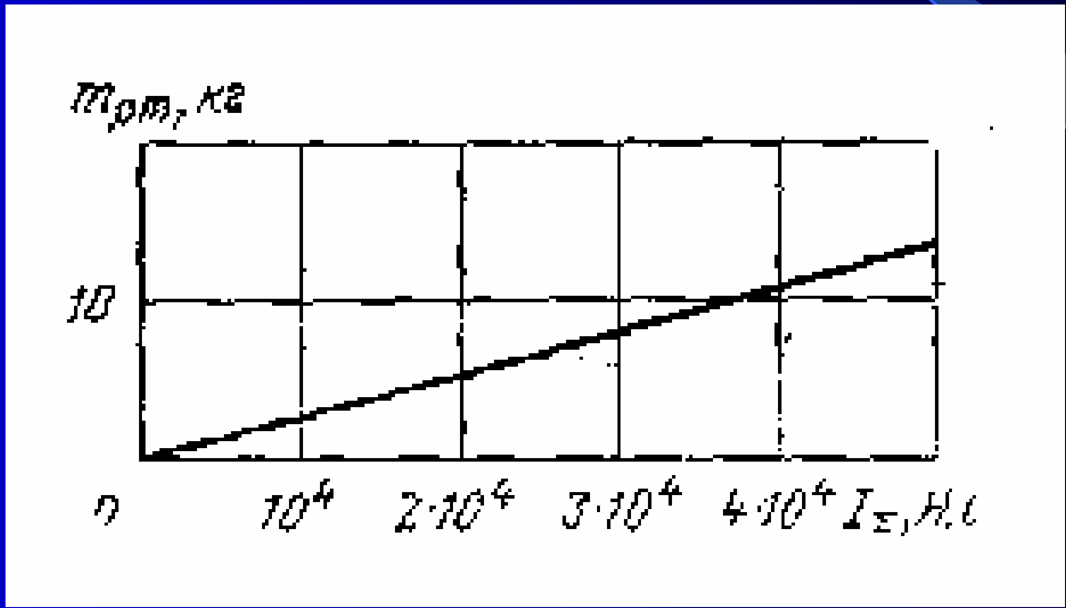


Fig. 3. 42. Dependence of weight of a propulsive mass on a total impulse of thrust during the usage of products of combustion of liquid bipropellant as a propulsive mass.

BIPROPELLANT LIQUID JET SYSTEMS

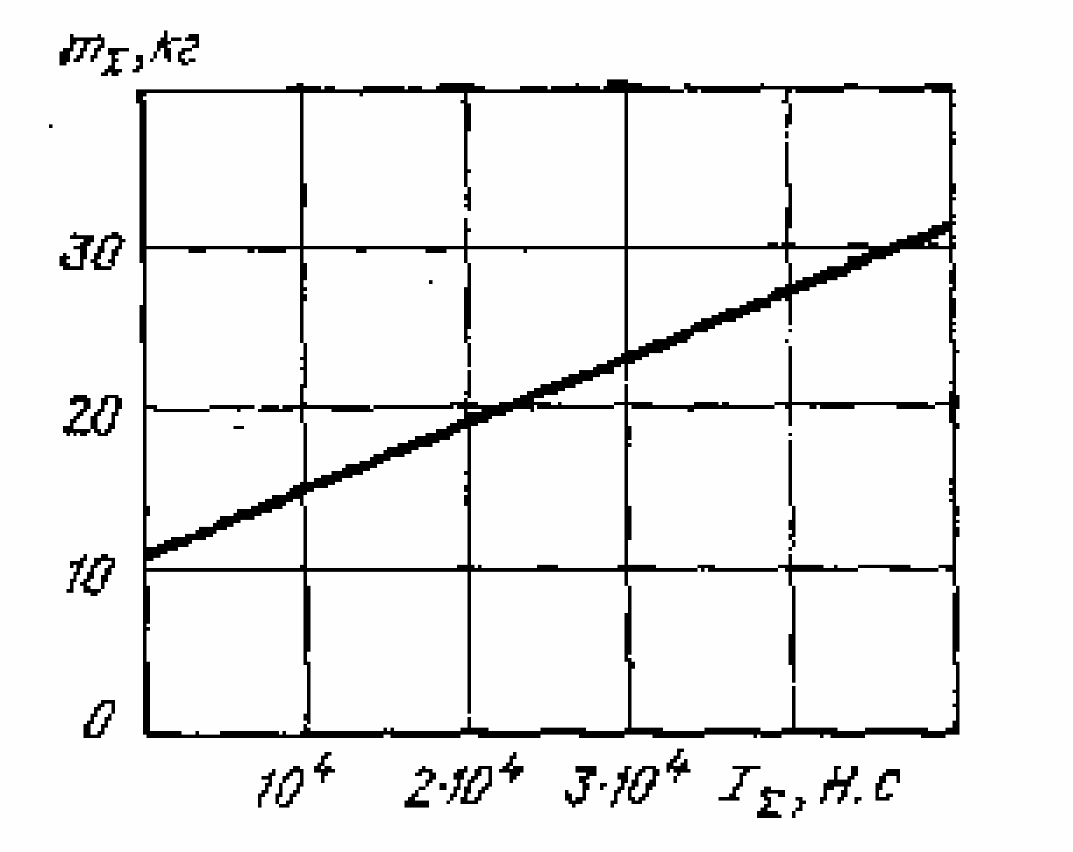
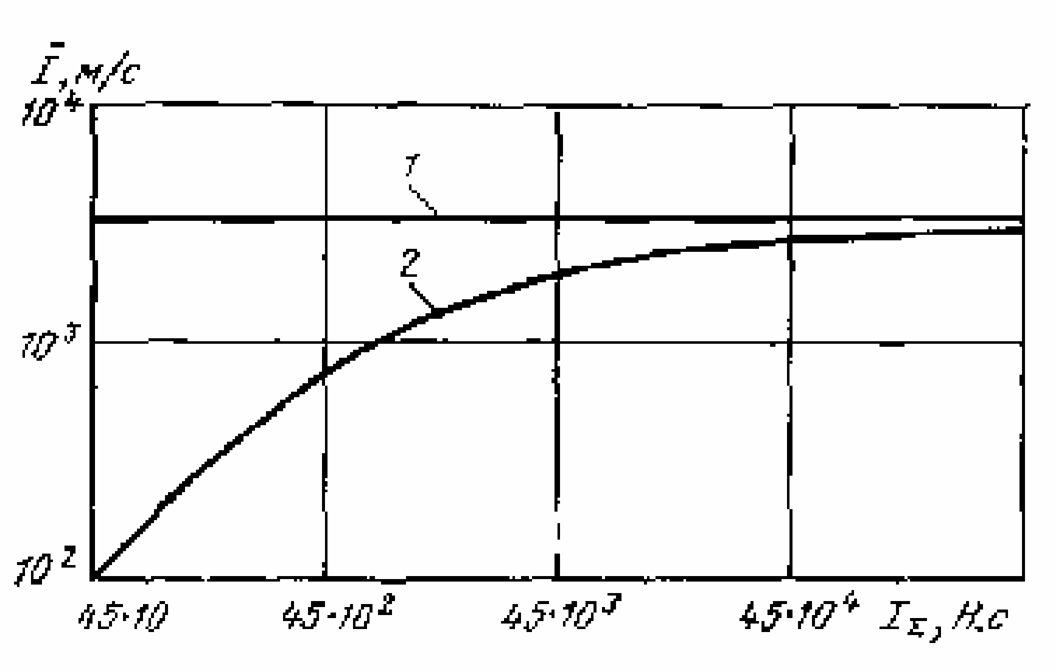


Fig. 3. 43. Dependence of weight of a jet system with twelve engines on a total impulse of thrust during usage of products of combustion of liquid bipropellant as a propulsive mass.

BIPROPELLANT LIQUID JET SYSTEMS



1 - specific impulse of propellant,
2 - a relative impulse of a system

Fig. 3.44 Dependence of a relative impulse of a system on bipropellant N_2O_4 +A-50 on an integral impulse of thrust at two thrusters R=225N, p_c=0.35 MN/m².
The combustion chamber is with radiation cooling, pressurant gas is N_2 (it is stored in bottles from titanium alloy).