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anti-aircraft missile COMPLEX “TOR-M1”

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anti-aircraft missile
COMPLEX “TOR-M1”

Tutorial

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The manual contains a technical description of the complex, rocket and its components. The features of the functioning of the means of detecting targets and guiding the missile, the flight trajectory, the algorithm for targeting the target, the principles of operation and the functioning of the main components of the missile, the sequence of operation of the missile as part of the complex and its main elements are described.

It is intended for students of the day and evening departments studying the discipline "Fundamentals of the device and design of rockets" at the faculties of "Rocket and space technology" and "Information and control systems".

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Reviewer prof. cafe "Rocket Science", Ph.D. tech. sciences, prof. *A.L. Isakov*

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INTRODUCTION

The main requirements that must be taken into account when creating anti-aircraft missile systems (SAMs) are determined primarily by the characteristics of the targets. The adoption of high-precision weapons, which have their own specific characteristics, has expanded the range of these requirements.

These characteristics are:
- small effective scattering surface of targets, especially in the front hemisphere, for the centimeter 0.1 m^2 wavelength range (1.5–5 cm);
– a wide range of heights (30–60 m – the lower level of flight altitudes) and angles (45–60º and more) the approach of the air defense system to the covered objects;
- a wide range of flight speeds (200 - 700 m/s) and available transverse overloads (8 - 10);

- a high level of protection for weapons, especially such types as guided bombs, shells.

Given these characteristics, the following general requirements for air defense systems can be distinguished:
– high degree of readiness (3–4 s);
- a short time for rocket acceleration to maximum speeds (3–5 s) and maintaining these speeds growth until the moment of hitting an air target;
- high maneuverability (available lateral overloads of at least 10);
- appropriate missile combat equipment capable of destroying heavily protected purposes;
- low cost of air defense systems (at the level of high-precision weapons used).

These requirements can be met through:
– high automation of the complex;
– the use of effective radar means of target detection and transmission commands on board the rocket;
– the use of powerful algorithms and computing tools for information processing, and tomatized missile tracking;
- constructive solutions that allow finding a compromise between the price and efficiency of air defense systems. The listed requirements are met by the Tor-M1 complex.

This manual provides general information about the complex "Tor-M1", its work and the cancer that it is equipped with. The device, features of functioning are considered in detail missiles and its elements in preparation for launch, during launch, in flight and when meeting with a target.

The manual is intended for students studying in specialties whose curricula contain disciplines related to the study of the structure and functioning of rockets. To facilitate the digestibility of the information contained in the manual, questions are given at the end of the text. for self control.

Based on these questions, an electronic version of the students' knowledge test was compiled.

The author is grateful to S.A. Chirikov and K.A. Afanasiev for technical assistance in the preparation of this manual.

List of accepted abbreviations

AP – autopilot,

ASA - starting automation equipment,

BIGG - block of sources of hot gases, BRU - on-

board radio control equipment,

BM - combat vehicle,

BCH - warhead

explosive, explosive

GG - gas generator

ZGURD - protective and sealing device of single action,

ZIP - spare parts, tools, fixtures, K1, K2 - the main control commands

for the autopilot,

KV - a command to cock a radio fuse, KZAZ - a

command to prohibit the asynchronous launch of the transponder,

KP - command to switch the mode of operation of the autopilot,

KRAZ - command to enable asynchronous launch of the transponder,

KU - ejection device, KUV - command to control the

cocking of a radio fuse, KOS - command of the relative speed of approach

of the missile to the target, KPO - command to switch the rudder deflection angle limit,

KTO - a set of rigging equipment, KU - ejection device,

NLC - low-flying target,

PIM - safety-actuating mechanism,

PP - passive interference,

PU - starting device,

RV - radio fuse

Solid propellant rocket engine, SVR - rocket sighting station,

microwave - ultra high frequency,

SPK - command transmission station,

SRP - calculating and resolving device,

TZM - transport-loading vehicle, TPK - transport-launch

container,

UPR - command "Control", UPT - amplifier

- current converter,

HIT - chemical current source,

PAR - phased antenna array, EMF - electric machine

converter.

1. GENERAL

1.1. Complex 9K331 and its work

The autonomous self-propelled anti-aircraft missile system (SAM) 9K331 (“Tor-M1”) is designed to effectively cover troops and military facilities from modern and advanced air attack weapons, primarily high-precision weapons, as well as aircraft, helicopters, cruise missiles, guided air bombs and remotely piloted aircraft. It is a modernization of the 9K330 (“Tor”) complex, the tests of which were started in 1983-84. Estimated date of adoption of the 9K331 complex into service is 1988.

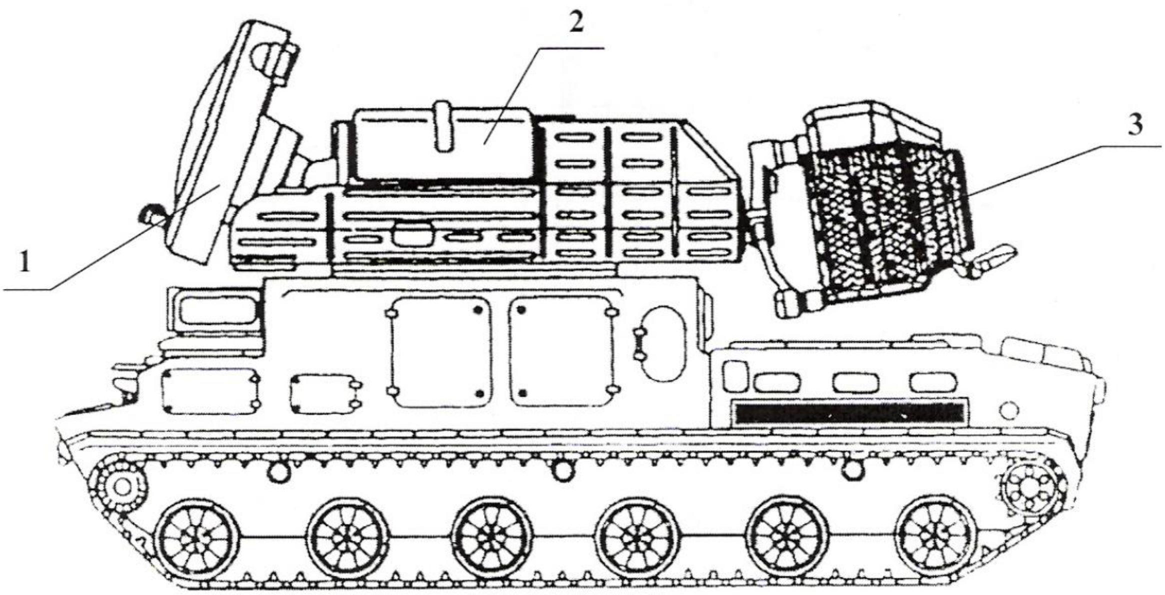
The Tor-M1 mobile all-weather short-range complex provides air defense of troops in mobile forms of combat and on the march, as well as in areas of concentration of troops, protection of the most critical military points (command posts, communication centers, radio equipment, bridges, airfields) .

The Tor-M1 air defense system differs from the previous ones in that all its combat information means, communications means and weapons are placed on one tracked chassis (Fig. 1) and represent a compact, functionally complete and technically perfect tactical unit - a combat vehicle capable of autonomously or as part of an air defense system, perform a combat mission throughout modern combat without additional refueling and loading, and at the same time round-the-clock (when refueling) all-weather combat duty and escort troops in battle or on the march.

Rice. 1. Autonomous military anti-aircraft missile system "Tor-M1"

The complex includes:

- 9A331 combat vehicle (Fig. 2) and 9M334 anti-aircraft missile module (9M331 missiles in transport and launch container 9Ya281, fig. 3);
- transport-loading machine 9T244;
- transport vehicle 9T245;
– maintenance vehicles 9V887M and 9V888-1M;
- a set of rigging equipment 9F116;
- group spare parts and accessories machine 9F399-1M1;
- autonomous electronic simulator for combat vehicle operators 9F678.



Rice. 2. Combat vehicle 9ÿ331:

1 - missile guidance radar (SVR, SPK); *2* – module compartment 9M334; *3* - detection station

On the basis of the combat vehicle 9A331 are placed:

- two anti-aircraft missile modules 9M334 (eight missiles 9M331) (Fig. 2, 3);
- three-coordinate target detection radar station *3* (Fig. 2, 4) together with ground radar interrogator;
– radar station for target tracking and guidance *1* with phased antennas array (SVR and SPC) and electronic beam control system (Fig. 2, 5);
- duplicating television-optical sight (Fig. 5), providing auto-tracking target positioning by angular coordinates;
– high-speed digital computing system;
- launch automation equipment (equipment for displaying information about the air situation and the cycle of combat work, as well as indicating the functioning of systems and means of a combat vehicle, working consoles for the commander and operators, auxiliary equipment);
– telecode operational-command radio communication system;
– equipment for navigation, topographical reference and orientation;
- system of functional control of the combat vehicle;
– autonomous power supply and life support system (primary power supply with electric generator driven by a gas turbine engine or self-propelled chassis propulsion engine).

To protect sedentary military, as well as civil and industrial facilities, constructive modifications of air defense systems have been developed: container, towed and wheeled versions. These modifications have the same tactical and technical characteristics, excluding mobility, but are somewhat cheaper than the self-propelled base.

Rice. 3. Module 9M334

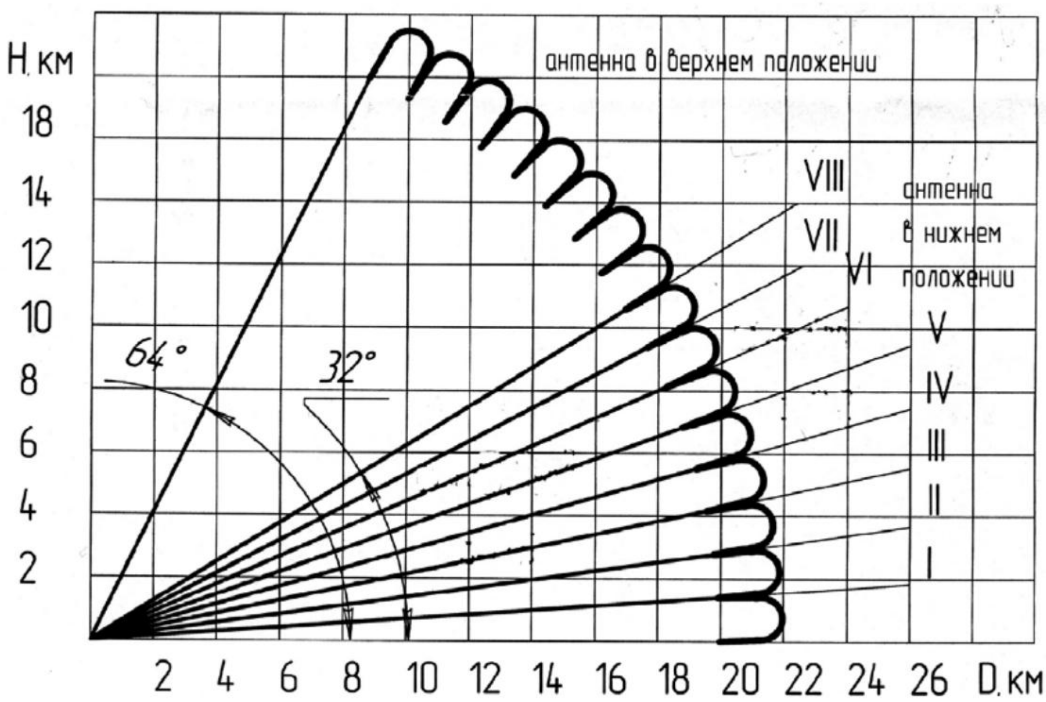
Rice. 4. Target detection station (SOC)

Rice. 5. Target tracking and missile guidance station (SVR and SPK) and backup television optical sight

Detection radar *3* (see Fig. 2, 4) is a coherent-pulse all-round radar. It operates in the centimeter wave band with frequency control of the beam in elevation. The average transmitter power is 1.5 kW, the resolution is not worse than 1.5 ... 2.0º in azimuth, 4º in elevation and 200 m in range. The maximum errors in determining the coordinates of the target are no more than half of the indicated resolution values.

The station is capable of detecting with a probability of at least 0.8 at a distance of 25...27 km F-15 aircraft flying at altitudes from 30 to 6000 m. Unmanned aerial vehicles are detected with a probability of at least 0.7 at a distance of 9...15 km helicopters hovering in the air -
with a probability of 0.6 ... 0.8 at a distance of 13 ... 20 km, helicopters with rotating propellers located on the ground - with a probability of 0.4 ... 0.7 at a distance of 13 ... 20 km. In this case, targets covered by active and passive interference can also be detected.

The detection radar provides a multipartial (8 partials - beams) [14] three-coordinate survey of space at a high rate. The scanning period is 1 s, the beam width in the vertical plane is 4º. Scanning of the angular viewing space in the vertical plane is mechanically divided into two ranges from 0…32º and 32…64º. This means that two batteries of the Tor-M1 air defense system can simultaneously view the zone in the angular raster 0…64º. An increase in the signal energy due to the use of a long pulse with intrapulse modulation and a mode of concentration of all radiation energy in one partial, three in one (Fig. 6), are provided.



Rice. 6. Scanning range of the angular space detection radar

The use of digital signal processing makes it possible to reliably detect both high-speed and low-moving (up to 10 m/s) targets without “blind speeds” in difficult conditions of passive (natural and artificial) interference, taking into account the influence of the underlying surface.

Signal processing is carried out by special computers and a central computer,
the computational and algorithmic capabilities of which make it possible to solve the problems of analyzing the air situation, making combat decisions, and other intellectual tasks of combat control.
eva operations.

The detection radar is coupled with a target nationality identification system and automatically blocks (with a high probability) the possibility of hitting “native” aircraft
body apparatus.

To enable the station to operate while the BM is moving, the position of the antenna is stabilized.

Guidance radar (SVR, SPK) (see Fig. 2, 5) coherent-pulse (pulse-Doppler type) radar. It operates in the centimeter wavelength range, has a low-element phased antenna array (PAR) that forms a beam, 1º wide in azimuth and elevation, and provides electronic scanning of the beam in the corresponding planes. Such an instantaneous (400…600 ms) transition to auto-tracking, as well as simultaneous tracking and firing of two targets in the PAR sector.
construction system allows provide practically

The station searches for a target according to the target designation data from the target detection station and captures one target for autotracking. With a probability of 0.5, the guidance station is capable of switching to auto tracking of a fighter aircraft flying at a range of 23 km. With a decrease in the range, this probability increases significantly, so, at a distance of 20 km, it already amounts to 0.8 [14].

The tracking radar signal processing system is digital monopulse with pulse compression and the corresponding signal processing algorithm, which provides not only high accuracy and noise protection, but also target class recognition, which allows optimizing the operating modes of the missile guidance system and its combat equipment.

The combat operation of the 9K331 air defense system takes place according to the scheme common for anti-aircraft missile systems. owls with a radio command guidance system.

The detection station in motion or on the spot performs a circular survey of the space, detects and identifies targets. The computing facilities of the combat vehicle analyze the air target, select the most dangerous targets for firing, and generate target designation data for the guidance station (command transfer station, SPK).

Guidance station (missile sighting station plus command transmission station) based on target designation data performs:

- search and capture of one target for auto tracking; - accurate tracking of the target in three coordinates; - launch of one or sequentially (after 4 s) two missiles at the tracked target;
– capturing the rocket after launch by a separate coordinator and introducing it into the beam of the phased antenna array;
- accurate missile tracking;
- control of missiles by commands generated by the difference in coordinates between the missiles and the target in accordance with the selected guidance method that corresponds to the most optimal small conditions for meeting a missile with a target, depending on its type, altitude and nature of the flight;
- issuing a command to delay its operation to the radio fuse of the rocket, depending on the speed of approach of the rocket to the target.

The main performance characteristics of the complex

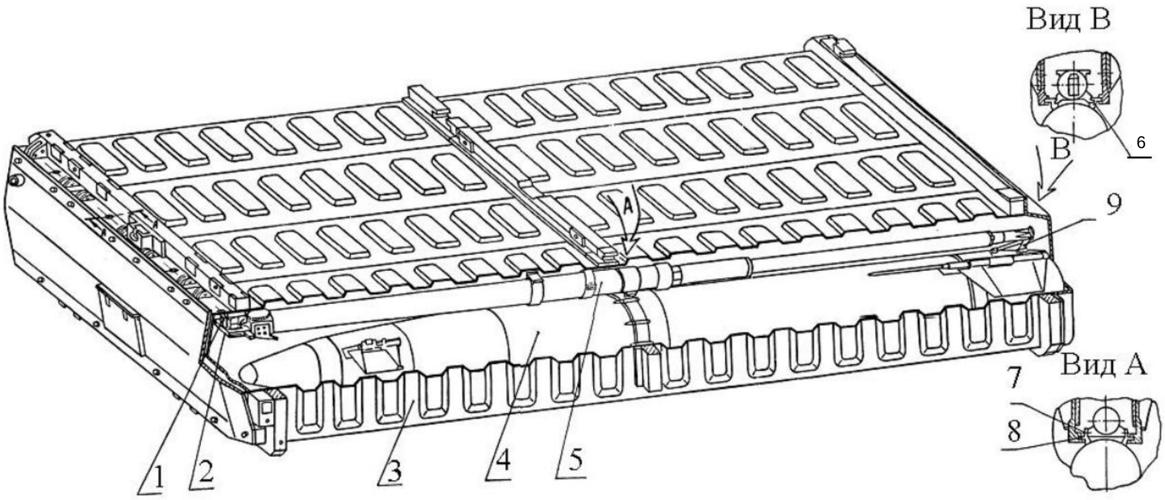
Number of simultaneously detected targets 48;
Number of simultaneously tracked targets 2;
Detection zone boundaries:
by distance, km 27;
in azimuth, city.. .... 360;
by the corner of the place, city ....0-32 or 32-64;
in height, km, not less than 23;
The boundaries of the affected area, km:
by distance, km 1-12;
in altitude, km in 0,01-6,0;
heading parameter, deg 6;
Speed of hit targets, m/s 10-700;
Maximum transverse overload of the hit target .... ten;
Minimum reflective surface of the target, m2 ....0.1;
The reaction time of the complex (from target detection to missile launch), s:
when firing from a position 7.4;
when firing from a short stop after movement 9.7;
The number of missiles on a combat vehicle .... eight;
Probability of being hit by a single missile ....
the aircraft (F-15 type)... .... 0.45-0.8;
helicopter 0.62–0.75;
cruise missile 0.93–0.97;
high-precision weapons 0.75-0.9;
Maximum speed of the basic version, km/h:
by highway 65;
on a dirt road 45;
Weight of combat vehicle, t 37;
Cruising range on fuel (with two-hour operation of the equipment), km 500;
Combat crew, including the driver 3

Operation of the complex is allowed at heights not exceeding 3000 m above sea level, at any time of the year and day, in various meteorological conditions in the ambient temperature range from -50ºÿ to +50ºÿ, in conditions of solar radiation and relative humidity of not more than 98% at temperature (30 ± 5)º ÿ and wind speed not more than 20 m/s [15].

The operating mode of the rocket equipment when switched on on the combat vehicle is cyclic: 10 minutes of work - 10 minutes of a break. After three inclusions, there must be a break of at least one hour. At any time of the break, a one-time activation of the rocket equipment for one minute is allowed to carry out the launch.

1.2. Anti-aircraft missile module 9M334

The 9M334 anti-aircraft missile module (see Fig. 3, 7) is a transport and launch container placed in a combat vehicle shaft in a vertical position. Each module contains four missiles.



Rice. 7. Anti-aircraft missile module 9M334:
1 - jumper; *2* - earring; *3* - container; *4* - rocket; *5* - ejection device; 6.8 - yokes; *7* - shear bolt; *9* - lever

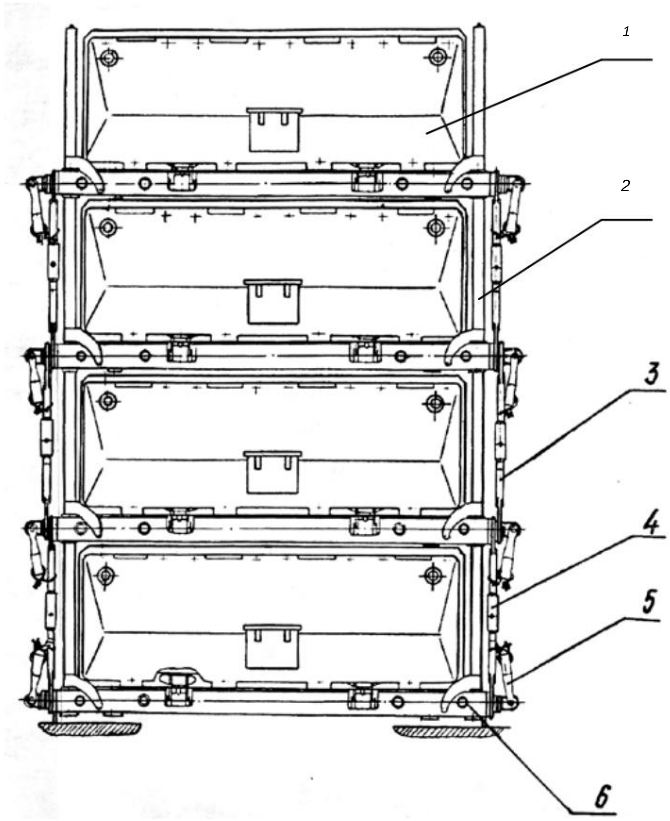
The 9M334 module is operated during the established service life without routine maintenance and checks of the on-board equipment of missiles.

Main parameters of the module

Mass of the module (TPK plus four missiles) with two beams, kg Mass of the 1053
TPK with two beams, kg... 333
Weight of one beam, kg 40 ....
Module dimensions with two beams, mm 539x1507x3005

Each module is equipped with two special beams, with the help of which the modules can be assembled into multi-tiered packages (Fig. 8). In such packages, missiles are stored and transported at all stages of operation, except for operation on a transport loader (TZM) and a combat vehicle (BM). The transport vehicle carries two packages of four modules and has crane equipment for loading the module into the combat vehicle.

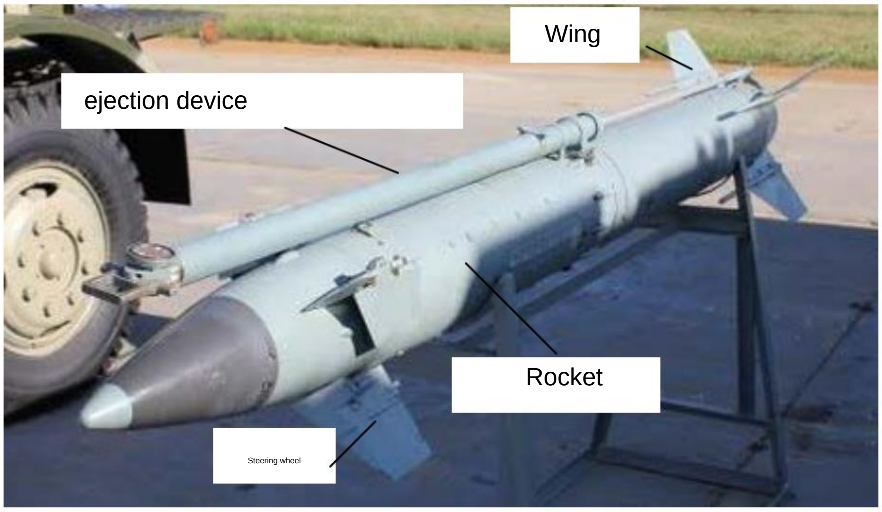
BM is loaded using a transport-loading machine. First, the module is transferred from a horizontal to a vertical position, then it is lowered into the BM shaft. The time for loading a combat vehicle with two modules is 25 minutes.



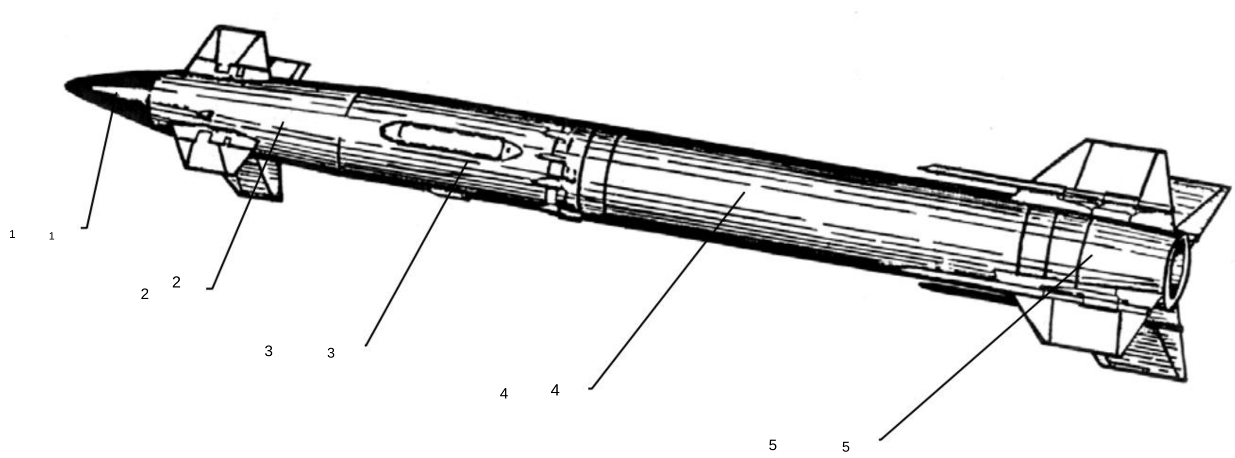
Rice. 8. Packing scheme for 9M334 modules:
1 - module 9M334; *2* - beam; *3* - coupler; *4* - clutch; *5* - bracket; *6* - nest

1.3. Rocket 9M331

A general view of the rocket is shown in fig. 9, 10. The rocket is made according to the “duck” aerodynamic scheme: the wings are located in the tail section of the rocket, the air control surfaces are in the bow. The rudders provide control of the missile's flight along a given trajectory and its stabilization relative to the longitudinal axis. The wings, together with the tail part of the body, form a wing block mounted on a bearing on the rocket body. In flight, due to the asymmetric flow around the wings and the hull, when the rudders are deflected and the rocket is maneuvering, an “oblique airflow moment” occurs, i.e., a roll moment. Under the influence of aerodynamic forces, the block rotates freely relative to the longitudinal axis of the rocket, excluding the occurrence of large roll moments.

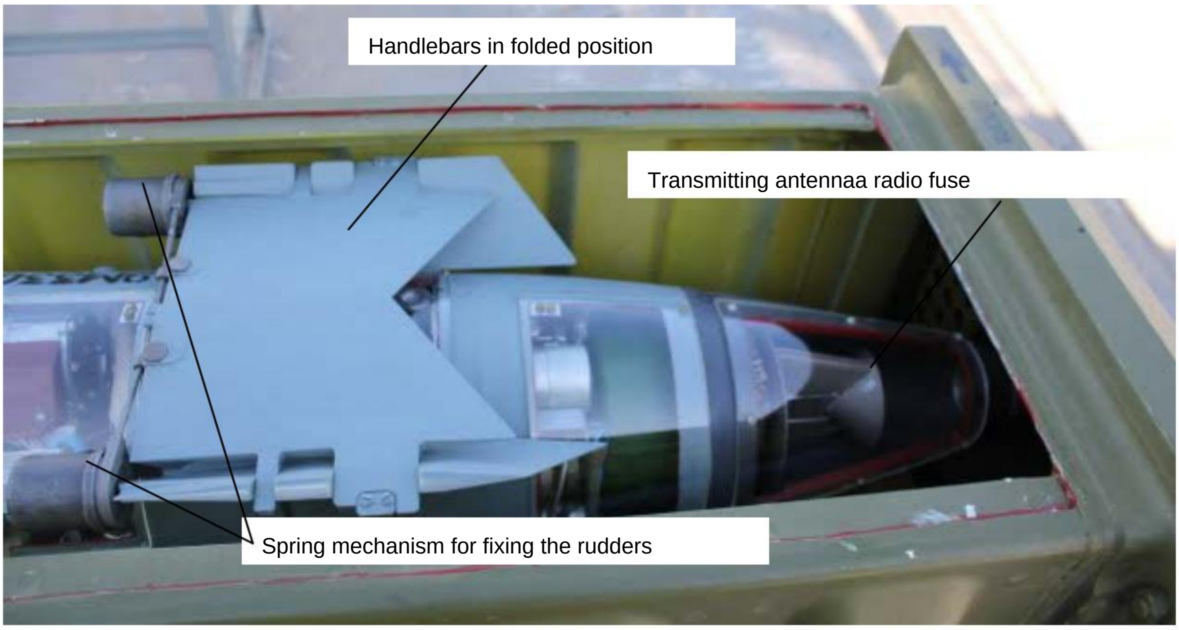


Rice. 9. General view of the 9M331 rocket



Rice. 10. Rocket 9M331:
1 – radio transparent fairing (first compartment); *2* - control compartment; *3* - instrument compartment; *4* - dual-mode engine; *5* - wing block

In order to minimize the transverse dimensions of the TPK, the wings and rudders of the rocket are made folding (Fig. 11, 12).



Rice. 11. The first and second compartments of the rocket in the container

Each missile is equipped with an ejection device (CD), which ensures the launch of the missile from the TPK. Fixation and fastening of each rocket in the TPK is carried out in three places. From transverse movements, the rocket is fixed by yokes *6* and *8* (see Fig. 7.9) and TPK guides along which it moves during launch. The longitudinal movement of the rocket in the TPK is excluded by the ejection device 5, one end of which is fixed with an earring *2* using a jumper *1* on the bracket of the TPK guide, and the other end rests with the lever *9* against the end of the rocket engine. Additional fixation is carried out by two shear bolts 7. The rocket and the ejection device have electrical connectors, through which they are connected to the BM automation equipment through the TPK harness and electrical connector.

The controlled flight of the rocket is provided by the onboard radio control equipment (BRU), autopilot (AP) and command block (BC) placed on the rocket.

Defeat of the target is ensured by combat equipment, consisting of an active radio fuse (RA), a safety-actuator (PIM) and a high-explosive fragmentation warhead (warhead).

The onboard equipment is powered from a chemical current source and an electric machine current converter.

Gas supply to the executive controls of the rocket is provided by two hardtops storm gas generators.

The propulsion system of the rocket is a solid propellant rocket engine that provides starting and marching thrust modes.

Basic performance characteristics of 9M331 missiles

Weight, kg 167;
Length, mm 2898;
Midsection, mm 239;
Wingspan, mm 650;
The span of the rudders, mm 530;
Mass of warhead, kg 14.8;
Warhead .... High-explosive fragmentation;
Maximum rocket speed, m/s .... 700 - 850;
Minimum maneuvering speed up to, m/s 300;
Maximum available transverse
overload 15-16;
Weight of the ejection device, kg 9

Questions for self-control in section 1

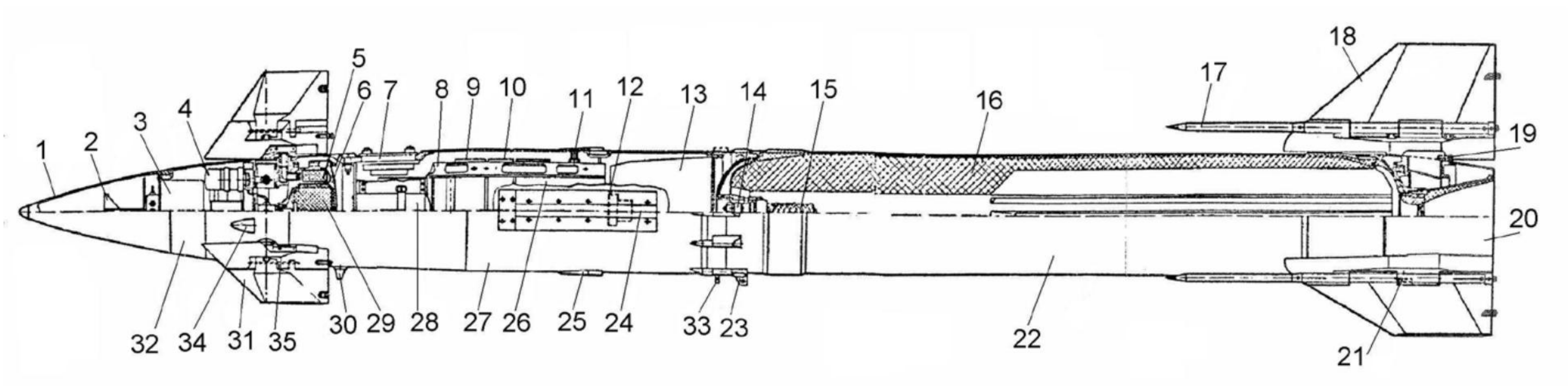
1. What is the 9M334 anti-aircraft missile module?
2. List the composition of the complex.
3. What is placed on the base of the 9A331 combat vehicle?
4. Give a description of the detection radar.
5. Why is the detection radar a coherent-pulse radar?
6. Appointment of the television-optical visa.
7. For what purpose and how is the survey of the space of the detection radar in the vertical planes?
8. How is the identification of the nationality of the target carried out? 9. List the functions performed by the guidance station.
10. Give a description of the guidance radar.
11. Phased antenna array (PAR), what is it?
12. Why is the guidance radar a coherent-pulse Doppler type radar?
13. List the functions performed by the guidance station.
14. What are the features of the operation of the complex and the mode of operation of the onboard equipment?
15. What does the concept of "blind speed" mean in radar?
16. The main features of the anti-aircraft missile module 9M334.
17. Advantages and disadvantages of the aerodynamic design of the 9M331 rocket.
18. Explain the operation of the ejection device.
19. Give a general description of the performance characteristics of the rocket.

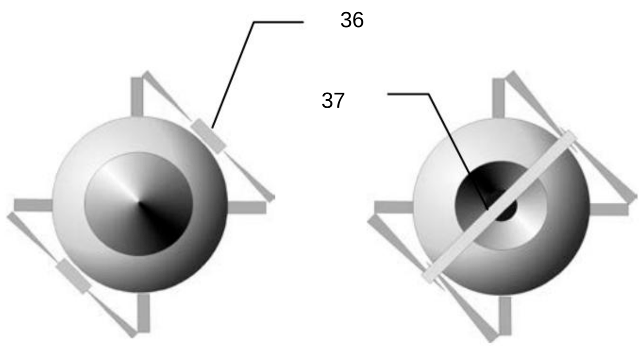
2. ROCKET DEVICE

The layout of the rocket is shown in fig. 12. The rocket body is divided into five compartments for convenience of its manufacture and subsequent installation of equipment.

The first compartment - nose cone *1* - is made of AG-4V radio transparent heat-resistant plastic to ensure the operation of the transmitting antenna of the radio fuse, which is attached to the front frame of the second compartment.

The second compartment is control compartment *32,* which consists of two welded parts made of AMG-6 alloy. Four air rudders-ailerons *31* are installed on the compartment body. In the compartment there is a block of hot gas sources 6, four gas steering machines *4* with gas wiring for their power supply, a radio fuse transmitter 3. Each steering wheel is driven by its own steering machine.





Rice. 12. Rocket layout: *1* - radio transparent fairing; *2* - transmitting antenna of the radio fuse; *3* - radio fuse transmitter; *4* - steering machine; *5* – gas generator charge of the declination system; *6* – block of hot gas sources; *7* - onboard electrical connector; *8* – stringer for fastening the onboard equipment; *9* - autopilot; *10* - radio fuse receiver; *11* - device for switching letters; *12* - safety-actuating mechanism; *13* - warhead; *14*- _
pressure alarm; *15* - igniter; *16* - charge of solid fuel; *17* - torsion bar; *18* - wing; *19, 21, 23* - rocket yokes; *20* – tail section; *22* – solid propellant rocket engine; *24* - receiving antenna of the radio fuse; *25* - antenna onboard radio equipment; *26* - on-board radio equipment; *27* - equipment compartment; *28* - onboard power supply; *29* - charge of the gas generator powering the steering gears; *30, 33* - lever; *31* – rudder-aileron; *32* - control compartment; *34* - fitting; *35* - locking mechanism, *36* - spring locking mechanisms of the rudders; *37* - jumper

The block of hot gas sources has two isolated chambers with charges of solid propellant: a central one with a charge of *29* for powering steering gears and an outer annular chamber with a charge *of 5* to power jet devices of the declination system.

From the central chamber of the block, gas enters the gas wiring and is distributed over the steering wheel vym machines, and from the exit of the steering machines is displayed overboard of the rocket through the fitting *34.*

From the annular chamber, the gas is discharged into the receivers of the jet devices formed in the body of the rudders *31.* In the front part of the compartment, the transmitter of the radio fuse 3 is located, fixed on the front end frame. Transmitting antenna mounted on the body of the radio fuse *2*

is located in the area of the first radio-transparent compartment.

The air rudder-aileron has a folding console. To hold in the folded position and open the steering wheel, a spring mechanism *36 is used,* held by a curly groove on a special bracket - the tip of the steering wheel at the rear edge. The device of the spring mechanism is shown in fig. 15. After the rocket is ejected from the TPK, the steering machines turn the rudders, the rudders open and the spring mechanism is dropped from the tip. In the open position, the steering wheel is fixed with a spring retainer (pin) *35* (see Fig. 12), located in the plane

steering wheel.

The third compartment - instrumental *(27)* - serves to accommodate on-board equipment (except for the radio fuse transmitter), power supplies and electrical switching equipment, as well as a warhead with a safety-actuator. The shell of the compartment body is also made of AMG-6 alloy.

The equipment block includes an autopilot 9, a radio fuse receiver *10 ,* and a control radio equipment. The elements of the equipment block, the chemical current source (two batteries) and the electromachine current converter *28* are combined into a single unit, being fixed on the stringers 8. The stringers are attached to the compartment body with radial screws. Warhead *13* cantilever mounted on the rear frame of the compartment. Precautionary

the actuator *12* is installed in front of the central channel of the warhead.

In front of the third compartment there is an onboard electrical connector *7* of the rocket. Two transceiver antennas of the onboard radio control equipment *25* are installed flush with the housing. In the middle part of the compartment there is an approach to the device for switching the letter frequencies of the onboard radio equipment *(11).* In front of the compartment, below, there is a rotary lever *30.* When the rocket is launched, when the lever is turned, pushbutton switches are activated in the onboard electrical system. Below, in the rear part of the compartment, the second rotary lever *33* is used to duplicate the launch of the rocket engine.

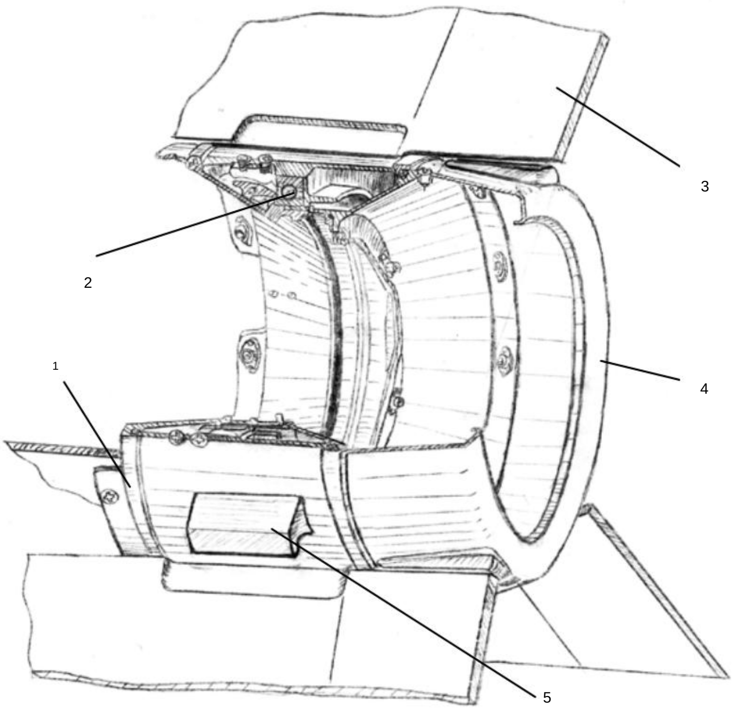
On the front and rear docking frames of the compartment there are bosses for connecting the compartment with the neighboring ones: the second (bolts) and the fourth (studs).

The fourth compartment **is a** dual-mode solid propellant rocket engine *22* - consists of a housing and a charge filled into it. The charge of the engine ensures the operation of the engine on the starting and marching sections of the rocket flight. When the engine is running, the charge burns through the internal channel and slots. The presence of slots provides, at the beginning of the engine operation, the starting mode of increased thrust with its subsequent decrease to the marching mode. The duration of the starting section is 4 s, the marching section is 8 s. Total running time 12 s. The engine has an unregulated nozzle, which ensures normal operation in both modes over the entire temperature range of rocket operation.

An igniter, squibs for igniting the igniter, and a pressure indicator in the combustion chamber are installed on the front bottom of the engine, which is used to maintain the PIM power supply circuit in the initial state during the rocket ejection. To duplicate the start of the engine, an electric igniter with a second delay is installed in the front bottom. On the rear bottom there is a cylindrical landing belt, on which it is installed under

spike of the fifth compartment.

The fifth compartment is the wing block *20,* which forms the tail section of the rocket. Four folding wings *18 are fixed on the body of the block,* the opening of which occurs with the help of torsion bars *17.* Two wings are fixed in the folded position by a jumper *37,* the other two are kept from opening by fixed wings. After starting the engine, the jumper is destroyed and the wings open. The general view of the wing block is shown in fig. 13.



Rice. 13. Rocket wing block:
1 - ring belt; *2* - bearing; *3* - block of wings; *4* - fairing; *5* - yoke

Yokes *21* are installed on the engine housing for communication with the ejection device. In the front part, the compartment has a ball bearing, the outer race of which is fixed in the compartment, and the inner one - on the bottom of the engine. Under conditions of ground operation, the compartment is kept from turning by an ejection device mounted on the rocket body. During the flight of the rocket, the compartment rotates freely relative to the longitudinal axis under the influence of the air flow.

flowing wings.

External views of the compartments are shown in fig. fourteen.

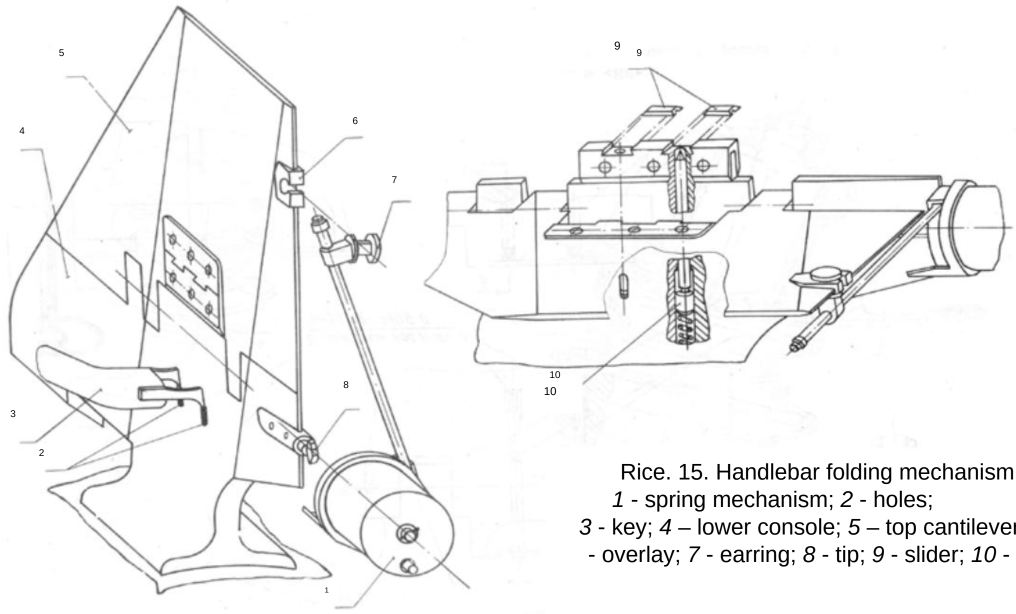
The second compartment is the control compartment

The third compartment is instrumental

The third compartment is instrumental

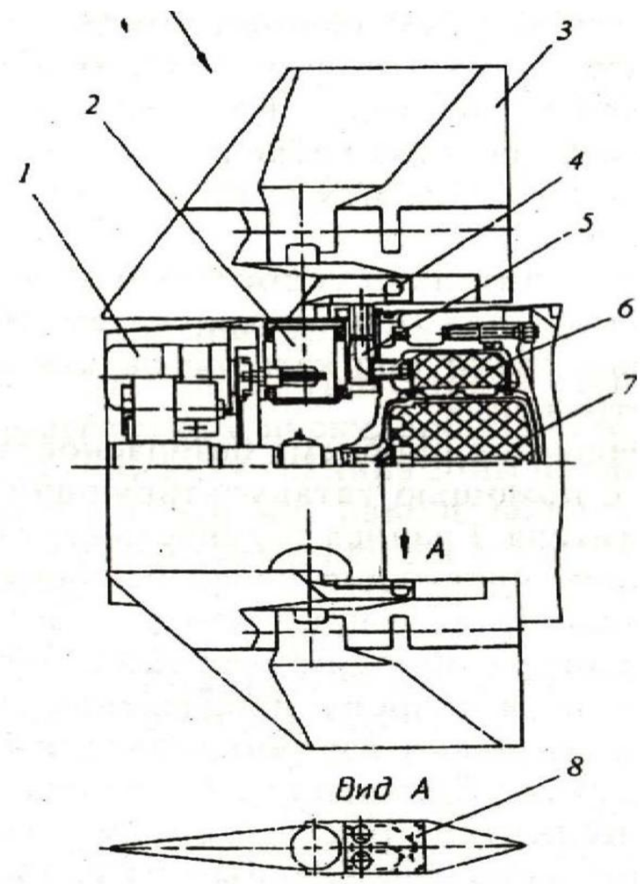
Fifth compartment - wing block

Rice. 14. External views of the rocket compartments



Rice. 15. Handlebar folding mechanism:
1 - spring mechanism; *2* - holes;
3 - key; *4* – lower console; *5* – top cantilever; *6* - overlay; *7* - earring; *8* - tip; *9* - slider; *10* - pin

The jet device of the rudder (Fig. 16) has two receiving holes adjacent to the feed channel. It works on the principle of a jet relay: when the steering wheel is deflected, the receivers from The outlets are located asymmetrically with respect to the supply channel and receive different amounts of gas. The outlet openings of the jet devices are made in the form of two oppositely directed supersonic nozzles. When the gas flows out of the nozzle, a thrust is created, proportional in magnitude to the amount of gas entering it and directed perpendicular to the plane of the rudder. The resulting lateral thrust of the nozzles provides control of the rocket in the first second of flight, when the flight speed is low and the lift forces of the rudders are insufficient to create the required control moment.



Rice. 16. Gas-dynamic device for declining a rocket: *1* - steering gear on hot gas; *2* - the axis of the steering wheel; *3* – steering console; *4* – gas jet nozzle; *5* - internal gas pipeline; 6 – declination system gas generator; *7* – gas generator of steering gears; *8* - outlet gas pipeline

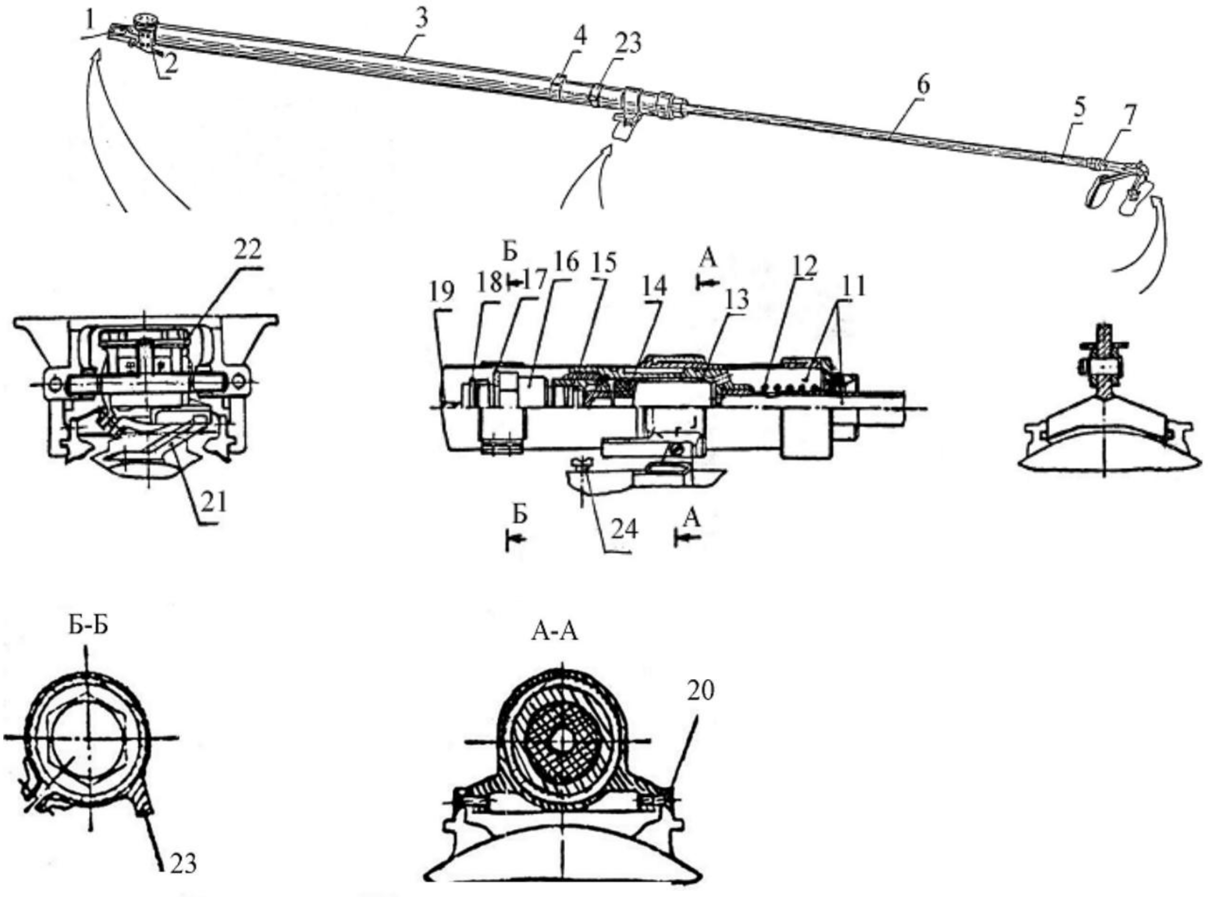
The ejection device (Fig. 17) is designed to ensure the launch (piloting roll) of the rocket from the TPK.

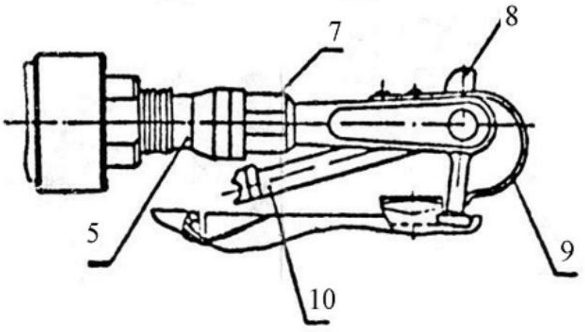
The ejection device consists of two parts: fixed (cylinder 3) and movable (rod 6). At the front end of the cylinder *3* there is a bracket *22,* on which an electrical connector for connection with the electrical system of the TPK, an earring *1* and an emphasis 2. Using an earring and a clamp *4 ,* the cylinder is attached to the container. With the help of the stop, when the rocket moves along the TPK guides, the front lever on the third compartment is rotated, which includes push-button switches for the rocket's electrical system. At the other end of the cylinder there is a stop *23,* designed to duplicate the engine start using the lever *24.* Inside the cylinder there is an electrical harness *19,* which is connected to the squib *16* using the electrical connector *18.*

Rod *6* is a turned pipe, at one end of which piston *13 is attached,* and at the other end - brake pipe *5* and lever *10.* Powder charge *14* is installed in the piston housing *13* and squib *16.* Brake pipe *5* softens the load on the TPK body when braking the ejection device.

The rocket is connected to the ejection device using shear bolts *20* and ry Chaga *10,* pivotally connected to the rod 6.

The ejection force is transmitted by the stop of the lever *10* in the end of the compartment *4* of the rocket. To hold the rod in the working position until the rocket is launched in the area of the free volume of cylinder *3* a spring *12 is* installed to maintain a constant force on the rod.





Rice. 17. Ejection device: *1* - earring; 2.8 - emphasis; 3- cylinder; *4* - clamp; *5* - brake pipe; *6* - stock; *7* - thrust; *9.12* - spring; *10* - lever; *11* – preliminary volume; *13* - piston; *14* - charge; *15* - sleeve; *16* - squib; *17* - washer; *18* - electrical connector; *19* - electrical harness; *20* - shear bolt; *21* - lever; *22* - bracket; *23* - a collar with an emphasis; *24* - lever

Questions for self-control in section 2

1. What is the first rocket compartment?
2. What is placed in the second compartment of the rocket?
3. Purpose of hot gas sources located in the second rocket compartment.
4. How does hot gas get into the rudder nozzle? 5.
Explain the operation of the spring locking mechanism of the rudders.
6. What is located in the third compartment of the rocket?
7. List the composition of the equipment unit
8. How and when is the rocket letter frequency set?
9. List the composition of the equipment unit.
10. Composition and purpose of the elements of solid propellant rocket motors.
11. How are the wings held in the folded position and how and when do they open?
12. What is the purpose of a wing block mounted on a bearing?
13. How is the rocket switched to onboard power?
14. The order of operation of the ejection device.
15. What is the sequence of functioning of the rocket elements during ejection
research institutes.
16. What happens to the rocket immediately after it leaves the TPK?

3. COMBAT WORK OF THE ROCKET

Loading TPK in the BM is carried out by a transport-loading machine. Before loading, the front removable cover is removed from the TPK, while the protection of the internal cavities of the TPK with missiles is provided by a one-time protective and sealing device.

TPK are installed in the BM shaft in a vertical position. Rocket launch is vertical.
TPK in the combat vehicle is mounted in the longitudinal and transverse directions. From longitudinal movements, the TPK is fixed by fixing the front frame of the TPK with the BM grips by the support plates. Transverse fixation is provided by the pins of the combat vehicle, which are included in two holes in the front frame, and the BM guides and T-shaped yoke grooves in the middle frame, which include the BM guides.

When loading, the missiles are equipped with lettered frequencies (missile addresses) and forging electrical connectors for TPK and combat vehicles.

The launcher in the BM provides a missile turn in azimuth to align the missile's declination plane with the direction to the target. The flight of a missile in the process of combat use has three characteristic stages: ejection,

turn in the direction of the target (declination), and aiming the missile at the target according to radio commands from the ground facilities of the complex. The flight of the rocket is preceded by the functioning of the onboard equipment in the “Preparation”, “Waiting” and “Start” modes.

3.1. Pre-launch and launch

Preparation of the rocket for launch is carried out with the help of the launch automation equipment installed on the combat vehicle.

During the preparation process:

– promotion of the onboard electric machine current converter and autopilot gyroscopes from a ground power source;

– power supply of the onboard equipment with all types of consumed voltages; -

introduction into the autopilot of the declination commands that are worked out by the rocket in flight tonomically;

– control of the safety circuit of the safety-actuating mechanism;

– control of the cocking of the catapult squibs;

– control of the initial state of the onboard automation;

- with access to the mode of the electric machine converter, switching to it onboard output consumers on alternating current circuits;

- receipt of a number of service commands and signals.

The design of the combat vehicle and the launcher with TPK allow you to direct missiles at azimuth to align the declination plane with the direction of the target.

If no “Launch” commands are received immediately upon completion of the preparation, the rocket is switched to the “Standby” mode, during which the launch or launch can be canceled at any time, with all supply voltages, commands, and signals turned off.

In the "Standby" mode, which, in principle, may be absent, within 0.05 s after the end of the "Preparation" mode, the power supply of the onboard radio equipment is switched from the ground source of alternating voltages to the onboard one. The duration of the Standby mode can be up to 60 s.

On command "Start" are produced:

– activation of the onboard chemical current source (CPS);

- with the output of the onboard HIT to the power supply mode from it to the onboard equipment Lelno with power supply from a ground source;

- input, if required, on the radio fuse of special one-time commands, introducing modes of operation on a low-flying target and in passive interference;

– memorization in the autopilot of the entered declination commands;

– gyroscope deregistration;

- Entering and recording the address of the rocket in the radio control unit.

Upon completion of these operations, a command is issued from the starting automation equipment to detonation of the catapult squib, which ignites the powder charge of the catapult.

With an increase in force on the catapult rod, which is transmitted to the rocket body, two locking bolts *7* are cut off (see Fig. 7) and the rocket begins to move along the TPK guides. With the beginning of this movement, the plug of the onboard electrical connector is undocked, and then, due to mechanical contact with special stops *2* and *8* (see Fig. 17) on the ejection device, levers *30* and *33* (see Fig. 12) on the third compartment are rotated, by closing the contacts of the corresponding pushbutton switches. As a result, the following occurs

- the gas generator powering the steering gears is started;

- in the command block, the device for generating time delays is turned on, which you gives commands to start the declination gas generator and rocket engine;

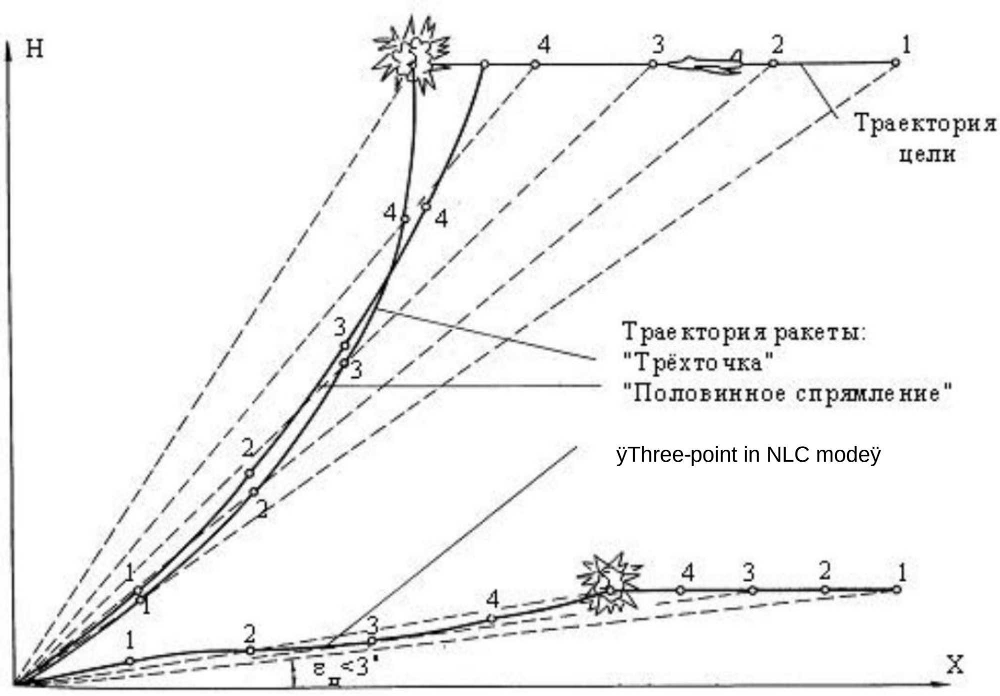
- a backup squib is launched (duplicating the launch of a rocket engine), which has a one-second delay in operation.

At the end of the stroke, the catapult rod is braked by compressing the gas in cylinder *3* and crushing the special brake pipe *5* (see Fig. 17) to reduce the impact load on the container. The rocket, having gained the required speed, continues to move by inertia to a height of 15-20 m.

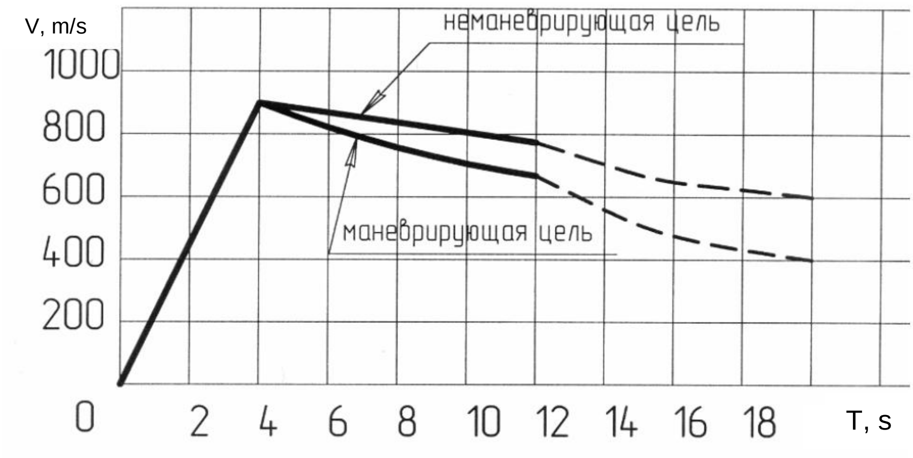
3.2. rocket flight

With the start of movement under the action of the toe of the rocket, the cover of the protective-sealing device of the TPK is destroyed. Immediately after the rocket exits the TPK, the time relay issues a command to reset the steering gears. The autopilot, based on information about the pitch and heading angles obtained from the launch automation equipment, generates a control signal according to a given algorithm and sends it to the steering machines. The rudders deviate, due to their rotation, the spring mechanisms *36* are released (Fig. 11, 12, 15), and the rudder consoles open, and the spring mechanisms are dropped to the ground. By this time, the declination system gas generator is started, and the gas enters the gas-jet devices of the rudders, creating a reactive force on the deflected rudders. The missile body begins to turn (declination) through an angle, the value of which depends on the trajectory of the subsequent radio-controlled flight (Fig. 18): from the minimum angle when firing at the upper near part of the target interception zone to the maximum angle when firing at a low-flying target at the near border of the interception zone.

The rocket engine is started by a signal from the command block. In the absence of a signal, the start is duplicated by a squib located in the igniter block on the front bottom of the engine. The flight time of a rocket with a running engine is 12 s. During this time, the rocket covers a distance of about 8 km, the maximum speed achieved at the starting leg of the flight is 850 m/s (Fig. 19).



Rice. 18. Scheme of the flight path of a rocket with various guidance methods



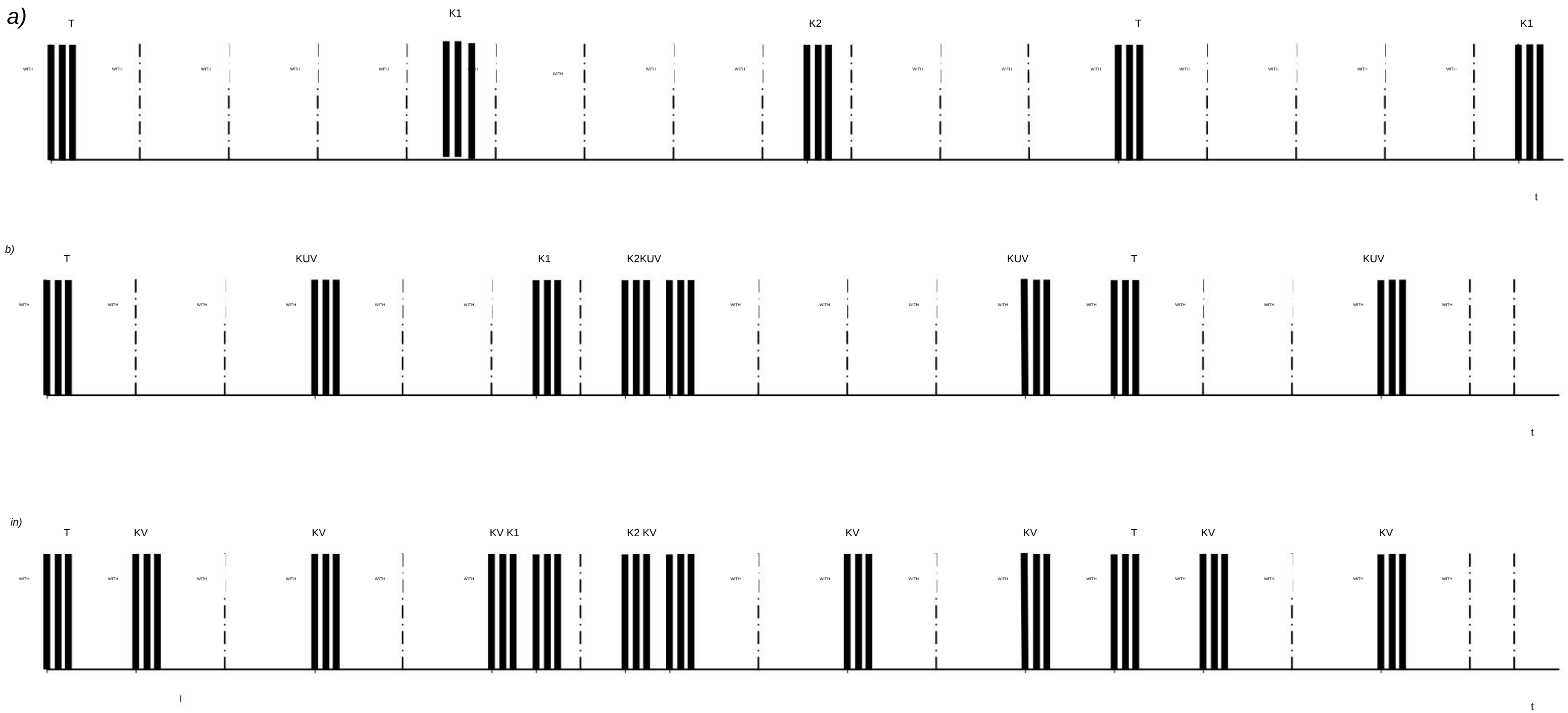
Rice. 19. Tor-M1 missile velocity profiles

The command block generates a signal to start the engine when the rocket reaches a declination angle of 50º or one second after turning lever *30* (see Fig. 12) located in the rear part of the third compartment under the catapult.

The declination gas generator terminates with some overlap after the engine is started. At this point, the rocket is picking up speed and the air rudders-ailerons become effective. At the end of the operation of gas-jet devices by the pressure drop in the gas generator
declination system, a command is issued to the autopilot to switch the limitation of the rudder deflection angles in order to increase the maximum values of their deviations in the control section.

During the flight of the missile in the initial section (100...150 m), it is captured for auto tracking by a guidance radar station located on the combat vehicle, and then the transfer of control commands begins. In this case, the SVR receives the signals emitted by the BRU and determines the position of the missile in terms of angular coordinates. The SPK emits signals with a code arrangement in accordance with the automatic launch equipment installed on the rocket.

Radio control commands are generated via two channels corresponding to the missile control planes and are transmitted by the command transmission station to the missile along with the “Request” signals (Fig. 20, impulse “3”).



Rice. 20. The total signal at the input of radio control and radio vision equipment:

a – before the one-time commands KUV and KV are given, the code combinations of the K1 and K2 commands to the left of zero-middle of the clock interval are positive, while the voltage at the output of the main channel of the UPT unit is positive, K1>0, K2>0 are shown conditionally; *b* - after a one-time command of the CWB is given; *c* - after a one-time HF command is given; "Z" - request pulse, T, K1, K2, KUV, KV - code combinations "Tact" and the corresponding commands

Upon request from the guidance station, the onboard transponder transmits response signals that ensure accurate missile tracking throughout the entire trajectory.

The radio control and radio vision equipment installed on the rocket receives radio commands K1 (pitch control), K2 (yaw control) from the command transmission station.

Commands K1, K2, KUV and KV are transmitted to the SPC in the form of code combinations (groups of pulses) with different spacing in time. The transfer of control command levels (K1, K2) is carried out by the phase-pulse method. The value of the command level is determined by the position of the code combinations of the command in a constant time interval - a cycle. This interval is determined by the distance between two adjacent code combinations “Tact” (“T”). The frequency of transmitting commands K1, K2 is equal to the frequency of the code combinations “Tact”.

A one-time command of the KUV is intended to turn on the transmitter of the radio fuse. The one-time HF command turns on the information processing unit and is designed to arm the radio fuse when the missile approaches the target. The command is transmitted at a frequency that is a multiple of the “clock” frequency during the transmission of two cycles.

In the final section of the trajectory, with a decrease in the flight speed of the rocket and, accordingly, the effectiveness of the aileron rudders, the command to switch the amplification factors in the autopilot is transmitted to the rocket. When the rocket approaches the target, upon command to arm the HF, the transmitter of the radio fuse begins to

irradiate the target. After the accumulation of a certain number of pulses reflected from the target and received by the radio fuse, a detonation command is formed in the executive circuit of the radio fuse, which is sent to the safety-actuator (PIM).

The safety-actuating mechanism, to which the warhead initiation circuits are connected, provides reliable protection against its unintended detonation in all operating conditions and during rocket launch - until the protection stages are removed in flight. During the launch and normal operation of the rocket engine, according to a signal about the presence of pressure in the combustion chamber (from the pressure indicator) and about the presence of a longitudinal overload of the required duration (from the inertial stop), the PIM is cocked. After that, at the detonation command from the radio fuse, the PIM fire circuit is triggered and the warhead is detonated.

In the event of a disruption in the normal flight of the missile, the transmission of flight control commands from the guidance station may be terminated. At the same time, from the onboard radio control equipment, after a certain time interval, a command is issued to the safety-actuating mechanism to eliminate the missile, according to which the warhead is detonated.

Questions for self-control in sections 3.1, 3.2

1. How is the 9M334 module equipped?
2. Characteristic stages of rocket flight.
3. How is the missile turned in azimuth in the direction of the target?
4. List the pre-flight modes of operation of the onboard equipment.
5. What is done in Standby mode?
6. What operations are carried out in the "Preparation" mode?
7. What operations are carried out on the "Start" command?
8. When is the command to launch a rocket issued?
9. What operations with the rocket are carried out during the operation of the ejection device things"?
10. When is the command to unzero the steering gears issued?
11. How is the control signal to the steering gears formed after the launch of the rocket?
12. How is the rudder unlocked?
13. How is the rocket controlled in the declination section?
14. When and how does a rocket engine start?
15. Why are the deflection angles of the rudders limited in the initial phase of the rocket flight?
16. When is the command to switch the rudder deflection limit switched? 17. How is the position of the rocket determined by angular coordinates?
18. When and how are the SPK commands transferred on board the rocket?
19. What commands are transmitted by radio control and radio surveillance equipment located on rockets?

20. What is the essence of transmission of control command levels (K1, K2) by the pulse-phase method?

21. What determines the time interval "Tact"?

22. When is the ECU command issued?

23. When is the CT command issued?

24. Appointment of PIM.

25. How and when is self-destruction of a rocket carried out?

3.3. Rocket flight dynamics

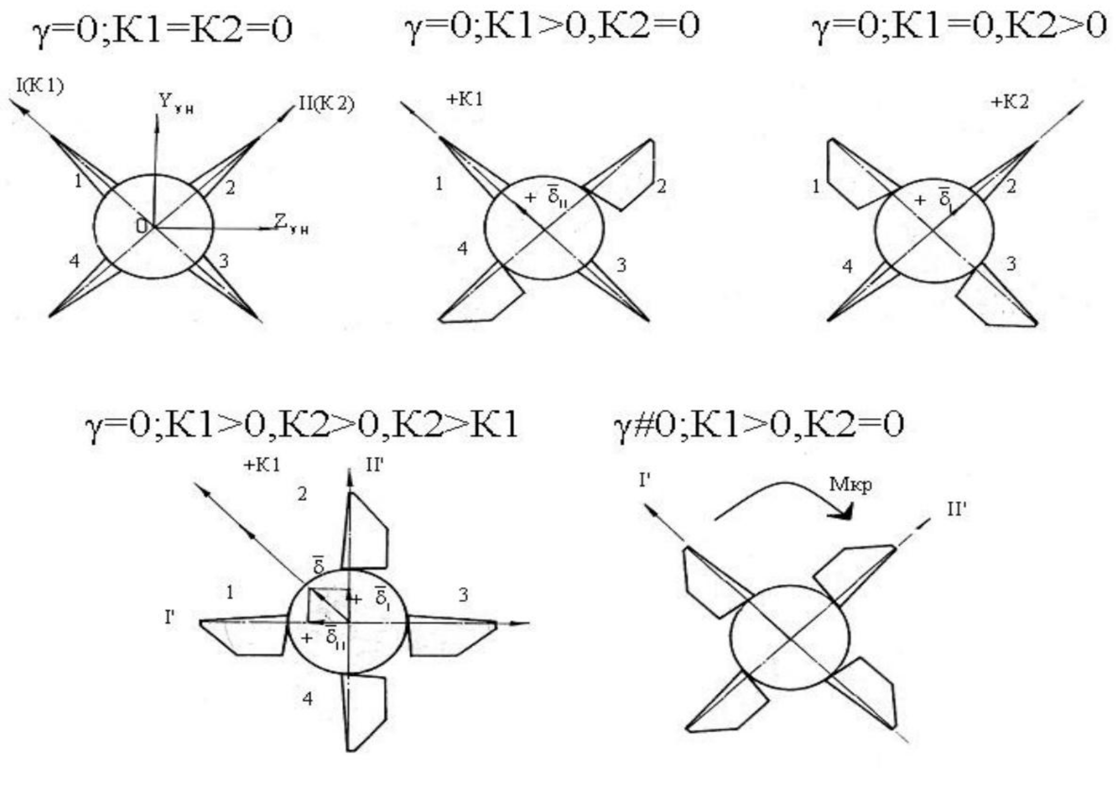
The rocket flight path can be divided into the following main sections: – initial uncontrolled vertical section (10…15 m);

- the declination section, where the missile is controlled in azimuth and elevation angles in accordance with a given algorithm and target coordinates embedded in the missile by the launch automation equipment (150 ... 200 m);

- a section controlled in accordance with the commands of the guidance station;

- the final section on which the missile is eliminated in the event of a miss. In the declination section, the rocket is controlled by a gas-dynamic method (see Fig. 16).

The nature of the trajectory in sections with one or another method of control in flight is determined by the magnitude and direction of the control force. The vector of this force, in turn, is determined by the orientation of the aerodynamic planes of the rocket (rudders and wings) in space, which is two-plane (x-shaped). Since in this case the lift force can be generated in any direction, no preliminary roll is required to perform the maneuver. The direction and amount of lift necessary for the maneuver are provided by an appropriate combination of angles of attack and sideslip. Therefore, the task of the computing device is to develop appropriate commands for two symmetrical control planes: K1 and K2 (Fig. 21).



Rice. 21. The principle of control of a roll-stabilized rocket

Guiding a missile to a target consists in continuous measurement and elimination of mismatch in the position of the missile relative to the kinematic trajectory determined by the guidance methods.

The guidance method ("half straightening" method or "three points" method) (see Fig. 18) is selected depending on the type of target and its parameters (velocity, range, angular position).

When pointing using the "three points" method, the rocket, moving along a curved trajectory, is kept on the line of sight of the target all the time. This pointing method is the simplest in hardware implementation, instrumental errors of the equipment and fluctuations of the target and missile signals cause smaller random pointing errors than with the "half rectification" method. The disadvantages of the "three points" method include a large curvature of the kinematic trajectory and, as a result, large, increasing as it approaches the target, the required transverse overloads of the rocket.

When pointing using the "half straightening" method, the movement of the rocket at each moment of time is directed to the predicted point of the meeting of the rocket with the target. The essence of the method is that the current sighting angles of the missile and the target (azimuth and elevation) are determined taking into account the lead correction:

= ÿ + ÿ ÿ ÿ ÿ   ÿ ÿ (ÿ a h / 2), vv p c   ÿ / ÿ   ÿr t( );

ÿ = ÿ p + ÿ   h   (ÿ b ÿ h / 2) / ÿ, v v p c   ÿ / ÿ   ÿr t( ),

where , ÿÿ ÿÿ   ÿ,ÿ r ts are the sighting angles of the missile and the target (azimuth and elevation, respectively); *r(t)* - current distance between the missile and the target; *K* - lead coefficient, which determines the correction for lead.

As a result, the trajectory during guidance by this method is flatter and the required lateral g-forces over the entire trajectory and at the point of contact with the target are much less than with the "three points" method. When developing the lead angle in the "half straightening" method, the speed of approach of the missile to the target and the distance between them, as well as the angular velocity of rotation of the line of sight of the target, are taken into account.

If the target is low-flying (the elevation angle of the target is less than 3º), then in the vertical plane the missile is aimed at the target using the "three points in the NLC mode" ("slide") method, and in the horizontal plane - either by the "three points" method or by the "half straightening" method.

When using the "three points" guidance method, when firing at a low-flying target, the missile is guided along a trajectory lying above the target's line of sight by an amount hdb , depending on the distance between the missile and the target. Starting from a distance to the target of approximately 6 km, the value of hdb begins to gradually decrease, and when the distance between the missile and the target is reduced to 1.5 km, the missile will enter the line of sight of the target.

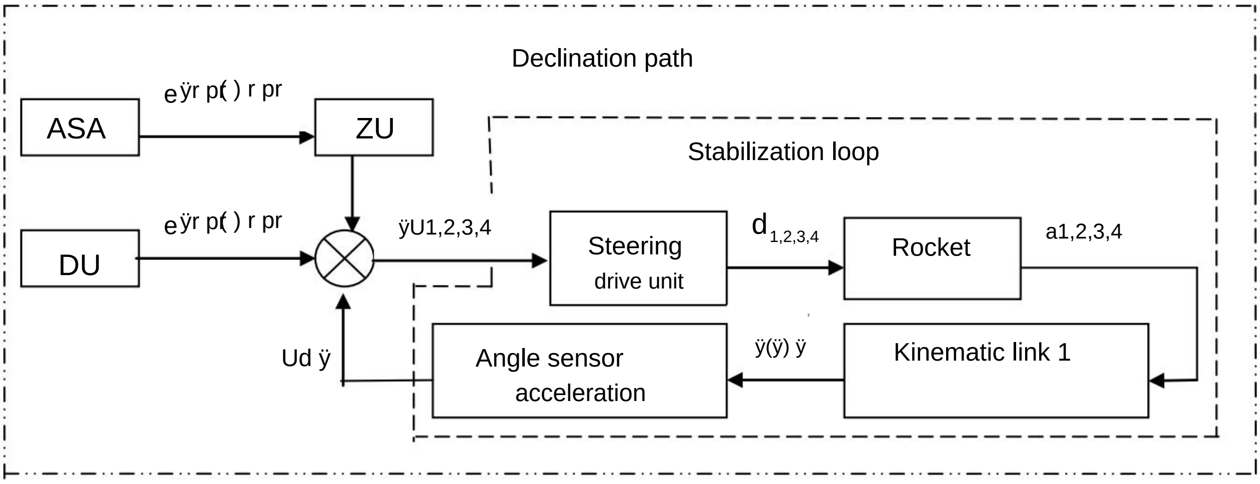
The "three points" pointing method when firing at a low-flying target ensures the flight of a rocket at a height that excludes the possibility of the rocket touching the earth's surface and false triggering of the radio fuse from signals reflected from it.

During the entire flight of the rocket, the autopilot stabilizes it relative to the transverse and longitudinal axes according to the signals of the acceleration and angle sensors. The stabilization of the missile and the reduction of its overshoot in terms of angles of attack and slip and overload is carried out by a stabilization loop formed by introducing negative feedback in terms of angles of attack and slip and roll angle. The block diagram of the declination and control paths with stabilization loops is shown in Fig. . 22.

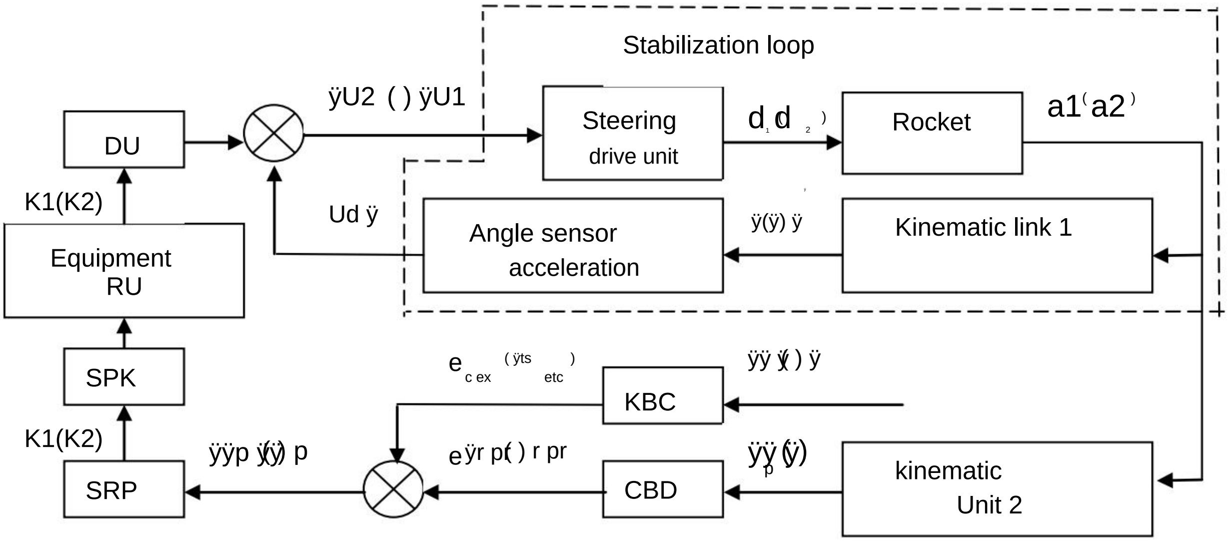
In the controlled flight segment, the missile and the elements of the control system (SRP, SPC, SVR) form a closed control loop, the characteristics of which determine the accuracy of pointing the missile at the target. The missile is controlled through two channels (pitch and yaw). Since both channels are identical, in Fig. 22 shows a diagram of one channel - the pitch channel.

During the entire controlled flight segment, radio control commands are sent to the missile, which are proportional to the linear deviations of the missile and their derivatives from the kinematic trajectory, the determination of which requires the measurement of the angular coordinates of the missile and the target. corner coordinates of the missile ÿ(ÿ) and the target ( ) ÿ are measured by coordinate blocks of the missile and the target (SVR and SPK equipment).

Kinematic links *1* and *2* are not material links of the control loop, but express the relationship between the angle of attack (slip) and the input values of the measuring devices.



Control path



Rice. 22. Simplified diagrams of the declination and control paths of the rocket:

ÿ 1(2) the angle of deflection of the rudders; (ÿ1 ÿ2) is the angle of attack of the rocket; EU (ÿc ÿyc) are the angular coordinates of the rocket and purposes; (pr ÿÿpr ÿÿ) is the angular mismatch of the rocket relative to the kinematic trajectory; DU - sensor corner; memory - storage device; ASA - starting automation equipment; SPK - command transfer station; SRP - calculating device; K1(K2) – control commands; U1n - feedback signal on damping gyroscope targets; ÿ(ÿ) is the angular velocity of the rocket relative to the transverse axis; CBC is the target coordinate block; KBR - missile coordinate block

Questions for self-control in section 3.3

1. *List the main sections of the rocket's flight path.*
2. *How are the rocket rudders oriented in flight?*
3. *How are commands generated to turn the rudders at roll angles* ÿ = 0 *and* ÿ ÿ 0 ?
4. *What is the essence of the three-point guidance method?*

5. What is the essence of the "half straightening" guidance method?
6. Advantages and disadvantages of the "three points" and "half straightening" methods?
7. Features of missile guidance when working on a low-flying target.
8. How is the possibility of the rocket hitting the earth's surface and false triggering of the radio fuse from the signals reflected from it?
9. What is a kinematic link?
10. What kind of feedback does the rocket as an object of regulation cover?

4. ONBOARD RADIO CONTROL EQUIPMENT

The onboard radio control equipment (BRU) is designed to receive information from the command transmission station, decode it, analyze and issue commands to the rudders, and generate a response signal for the missile sighting station. In this case, the radio equipment must receive, amplify, decode, form, in accordance with the signals received from the command transmission station and the starting automation equipment, the following commands:

- two main control commands for the autopilot: K1 and K2;
- commands for controlling and arming a radio fuse: KUV and KV;
– commands to disable and enable asynchronous launch of the transponder: KZAZ, KRAZ;
– commands "Relative approach speed" in the form of four values KOS1 – KOS4;
- the "Time" command to eliminate the missile in the event of a malfunction of the radio link on time more than 1.5 - 2 s;
- commands for switching the modes of operation of the autopilot (CP) and "Control". The on-board radio control equipment must also:
– convert request impulses into trigger impulses for their subsequent generation walkie-talkies and the issuance of missile sighting signals;
– issue zero values of control commands to the autopilot in case of radio link violation for more than 100 ms;
– provide frequency selection of the received signal on any of the given characters frequencies;
– receive from the equipment of the starting automation the commands "Product address", "Record";
– to decrypt commands at eight addresses.

To perform these functions, the following main blocks included in the application are used. radio control and radio vision parature:
– receiving antenna-waveguide system;
– receiver;
– command generation unit (decoder);
– transponder (radio imaging unit);
– transmitting antenna-waveguide system;
– DC amplifier (DCA).

4.1. Functioning of the onboard radio control equipment

During the loading of the TPK into the combat vehicle, the set value is set on the missiles with the key. letter frequency.

The onboard radio control equipment as part of the rocket before launch operates in the "Preparation", "Waiting" and "Start" modes, and after the "Preparation" mode, it is possible to immediately switch to the "Start" mode.

In the "Preparation" mode, power supply voltages of +20 V, -20 V, 3x36 V 1000 Hz, and +27 V are supplied to the radio equipment from the ground power source to turn on the forced mode of magnetron heating. At the same time, the address code is issued and the DC voltage is supplied through the "Record" circuit in the form of a logical "1" level. The asynchronous start inhibit circuit supplies +20 V.

AC voltage 3x5.2 V 1000 Hz from the onboard source reaches the nominal values after 1.0…1.5 s. As a result, the following mode is set on the radio equipment:
– there is a forced heating of the magnetron filament;

– issuance of an asynchronous launch pulse of the transponder is prohibited;

– the counting and output circuits of the block are reset by the “Write” command;

– in the initial state, the lower antennas are open and the upper ones are closed;

- the address code is set, issued by three circuits from the starting automation equipment.

The “Preparation” mode lasts 5 s. By the end of the fifth second, the radio equipment is ready for the “Standby” or “Start” modes.

In the “Standby” mode, for at least 0.05 s after the end of the “Preparation” mode, the power supply of the onboard control equipment is switched from the ground source of alternating voltage 36 V 1000 Hz to the onboard one. All other applied voltages correspond to the “Preparation” mode. The duration of the “Waiting” mode can be up to 60 s.

In the “Start” mode, the onboard voltages +20 V and –20 V from the chemical current source reach nominal values within no more than 1 s, and the power supply of the radio equipment through these circuits is transferred to the onboard sources. During the time 0.1…0.2 s before the moment of rocket launch, the voltage is removed in the “Record” circuit with the level of logical “1”ÿ . This command disables overwriting for 1.5…2.0 s address code during the detachment of the onboard connector during the rocket launch. With the detachment of the onboard connector, the voltage of +20 V is removed in the chain of the command to enable the asynchronous launch of the transponder (KRAZ). On this command, the asynchronous transponder launch mode begins in the onboard radio control equipment and transponder radio pulses are radiated into the air through the upper and lower antennas.

The missile sighting station receives signals emitted by the onboard radio control equipment, and determines the position of the rocket in angular coordinates.

During communication sessions, the command transfer station transmits signals of continuous and one-time commands to the rocket, request pulses with a code arrangement corresponding to the address code on the rocket set by the launch automatics (see Fig. 20).

At the beginning of each communication session, at the command of KZAZ, the asynchronous mode of starting the transponder is terminated and pairwise switching of antennas begins, while either the two upper antennas (receiving and transmitting) or the two lower ones are opened.

After double confirmation of the highest signal in one of the receiving antennas, this pair of antennas (upper or lower) opens and transmits the signal until the end of the communication session. This creates the best conditions for the operation of the radio link. Prior to the start of communication sessions and during breaks between them, the transponder of the onboard radio equipment operates in an asynchronous mode. In this case, the missile sighting station determines the position of the missile in terms of angular coordinates. During a communication session, the transponder is triggered by request pulses from the command transmission station and operates in synchronous mode. In this case, the missile sighting station determines the position of the missile by angular coordinates and range.

During the first passage of a communication session and commands K1 and K2 to the BRU, the radio equipment generates a “Control” signal in the form of a DC voltage of +27 V, which switches to the mode of processing control commands issued by the radio equipment (K1 and K2). The specified signal “Control” is blocked by the autopilot circuit, and if this signal is removed by the radio equipment, the autopilot does not switch to another mode of operation.

During the flight, as the command transmission station issues one-time commands, the BRU issues signals:

– to the autopilot – the command “Switching the autopilot operation mode”;

– to the radio fuse – four commands “Relative approach speed” in the form of a DC voltage corresponding to the logic “0” level, as well as the commands “Radio fuse arming control” and “Radio fuse arming” in the form of voltage +27 V.

In the event of a radio link failure for up to 100 ms or the absence of commands K1 and K2 in a row in three communication sessions, the “Control” signal is not removed, and the levels of commands K1 and K2 are remembered. If the radio link is broken for more than 100 ms, the “Control” signal is removed, and the commands are set to zero. When the radio link is restored, the “Control” signal is restored, and the command levels correspond to the levels transmitted by the command transmission station.

In case of violation of the radio link for a time of 1.5 ... 2.0 s, the BRU issues the “Time” command, which Paradise closes the chain for self-destruction of the rocket.

ÿ This means that the signals in the channel are transmitted in accordance with the high speed signaling protocol. According to this protocol, low voltage transfer of nominal voltages of logical “0” (max) and logical “1” (min) is carried out with a given difference relative to the nominal value. For example, the nominal control voltage is +20 V, then logic “0” can be equal to +20.2 V, and logic “1” +19.8 V. Using low voltage signals in the channel reduces power consumption and electromagnetic interference.

4.2. Command block

The command block is designed to generate commands to start the rocket engine and the gas generator of the rocket turn (declination) system. It consists of two main parts: a device for generating time delays and an algorithmic device.

0.31 s after turning lever *30* (see Fig. 12), the time delay generation device generates a command to start the gas generator of the turn system, and 1 s after turning the indicated lever, a command to start the rocket engine. The algorithmic device generates a command to start the engine when the rocket, in the process of turning, reaches yaw or pitch angles equal to or greater than ± 50º.

The signals of the current pitch and heading angles are sent to the command block from the autopilot.

To ensure the given level of reliability, the instrument uses two-fold redundancy of the channels of the algorithmic device and four-fold redundancy of channels in the device for generating time delays.

The command block is powered by a voltage of ± 13.5 V from a source included in the auto the pilot.

4.3. Autopilot

The autopilot as part of the rocket flight control equipment performs:

- control of the missile's flight along the trajectory in accordance with the commands K1 and K2 coming to it from the onboard radio control equipment;
- rocket turn in pitch and course in a given direction after a vertical launch;
- stabilization of the rocket's movement relative to its three mutually perpendicular axes.

The autopilot includes a control unit and four steering gears, which provide the necessary transformation and execution of control commands K1 and K2, as well as stable the distance of the rocket relative to the center of mass during its movement.

The control unit is a single unit that contains sensitive elements (two linear acceleration sensors, three angular acceleration sensors, three free gyroscopes) and an electronic unit (voltage stabilizer, time relay, and two boards with electrical and radio elements).

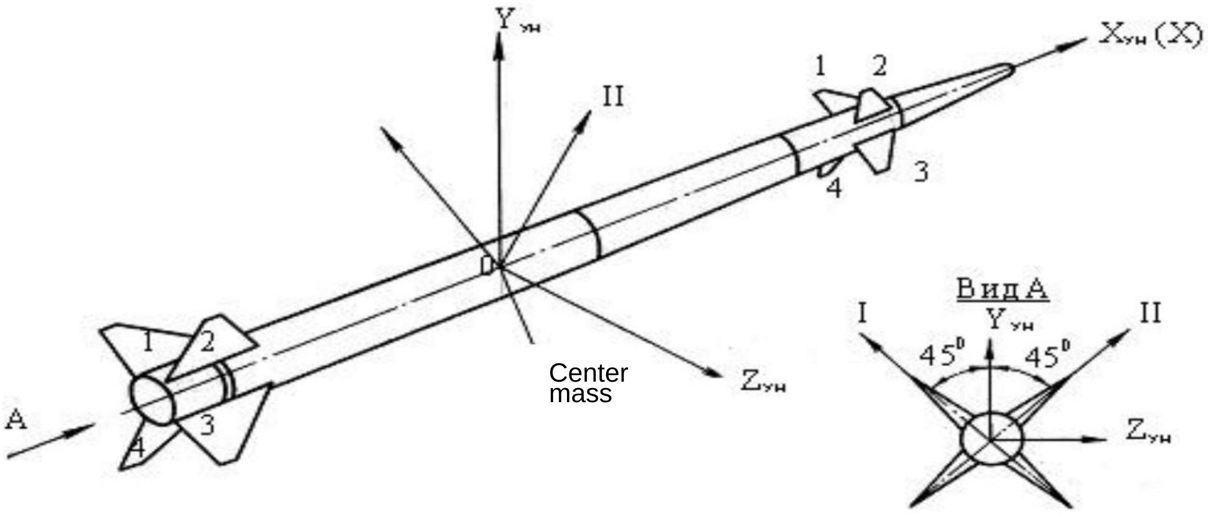
To determine the origin of the angles measured on board the rocket with the help of gyroscopic instruments, the starting coordinate system (conditionally fixed - Fig. 23) is used. Its center is located in the center of mass of the rocket at the moment the autopilot gyroscopes are uncovered. In this case, the *OS* axis at launch lies in the rocket declination plane and is directed in the direction opposite to the direction towards the target. The associated coordinate system is used to read the heading angles ÿ , ground clearance ÿ and roll ÿ relative to the starting coordinate system. The origin of the associated coordinate system also lies at the center tan of mass of the rocket. At the moment of rocket launch, the associated coordinate system coincides with the starting gyroscopic one. The associated unfolded coordinate system *OXI (II)* is used to measure the angular velocities of the rocket, the g-forces acting on the rocket, and the deflection angles of the rudders.

The rocket is controlled and stabilized relative to the center of mass in the declination section at subsonic flight speeds by the gas dynamic method, and then with the help of two pairs of air rudders. The location of the rudders relative to the associated coordinate system and the conditionally fixed (starting) one is shown in Fig. 23. Each steering wheel is driven by its own steering machine.

When operating the autopilot, the following modes of operation should be distinguished: before the start of the slope niya, declination, control.

Before the start of declination (height 15...20 m), the steering gears are set to zero, which is achieved by disconnecting the inputs of their amplifiers from the control signals.

The electrical circuits of the autopilot are powered by voltages of +20 V, -20 V and +27 V from the ground power source simultaneously with the activation of the gyro motors by the “Prepare” command. Since that time, the memory devices in the "Tracking" mode track the information about the pitch and heading angles received from the equipment of the starting automation.



Rice. 23. Conditionally fixed and bound coordinate systems

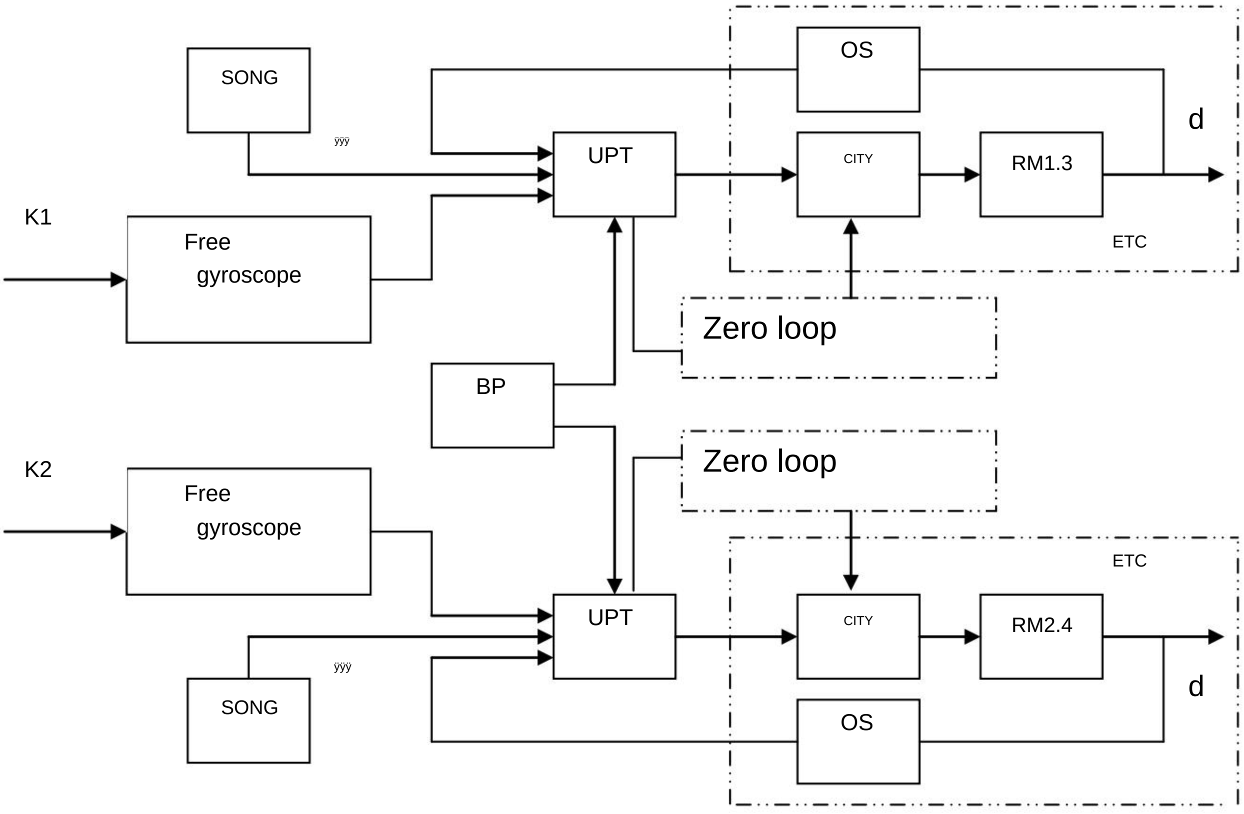
After 5 s, there is a transition from the ground power source to the onboard power supply by alternating voltage and, if the "Waiting" mode follows (maximum time 60 s), then two gyroscopes operating in freewheel flight are powered from the ground source with voltage (36 ± 1) V (1000 ± 100) Hz. At any time in the "Waiting" mode, the "Start" command can be issued, and after 0.9 s, commands are issued from the launch automatic equipment to unblock free gyroscopes and to transfer the autopilot memory device to the information storage mode ("Memory" command) about the value of the declination commands at the end of the rocket launch process.

After 0.9 - 1 s after the "Start" command is given, the launch of the rocket begins, during which the onboard connector is torn off and the transition from the ground power source to the onboard one along the +20 V, -20 V and +27 V circuits takes place. Through 0, 25 s after the missile's onboard connector is detached, the time relay is activated and the steering gears are reset.

The declination path (see Fig. 22) of the autopilot, based on the information about the pitch and heading angles obtained from the launch automation equipment and stored in the memory device in the "tracking" mode, generates a control signal according to a given algorithm and feeds it to the control left cars.

The principle of forming control commands K1 and K2 from a conditionally fixed coordinate system into commands UNI and UNII of the associated coordinate system (see Fig. 23) is as follows (Fig. 24). The control radio commands K1 and K2 in the form of two components of the main command vector $\bar{K}$ arrive at the input of the autopilot in the "X" system, i.e. parallel to the planes of the rocket rudders. The autopilot is made according to a two-channel scheme, each pair of rudders has its own steering path. Channel *I* is designed to control the missile's movement in accordance with the UNI command and its stabilization relative to the OI axis , channel *II* is to control the missile's motion in accordance with the UNII command and its stabilization relative to the *II* axis (see Fig. 13). At the moment the rocket leaves the container, the vectors of the control commands K1 and K2 are parallel to the planes of the rudders. With a positive command K1, the trailing edges of the rudders of channel *II* deviate downward (positive ÿ) and the rocket flies upwards to the left. With a positive command K2, the rear edges of the rudders of the channel *I* deviate downward (positive angle δ_1) and the rocket flies upwards to the right. So the vector deflection of the rudders $\bar{\delta} = \sqrt{\bar{\delta}_1^2 + \bar{\delta}_2^2}$ corresponds to the vector of the control command for the $\bar{K} = \sqrt{\bar{K}_1^2 + \bar{K}_2^2}$.

To work out the radio control command in the associated coordinate system and align the processing plane with the plane of the radio command from the onboard radio equipment, the command K1 (K2) is fed to the potentiometer of the free gyroscope *11* (see Fig. 26). The latter redistributes the received control commands between the planes of the pairs of rudders. The command from the free gyroscope is added to the signal of the stabilization circuit and goes to the steering gear, which deflects the rudders at an angle ( ) $d_1 d_2$.



Rice. Fig. 24. Structural diagram of the autopilot (pitch and yaw control): RM - steering machine, OS - feedback (RM feedback potentiometer), GR - gas distributor (jet relay), DUU - angular acceleration sensor, DU - angle sensor, PR - steering gear

The deflection of the rudders leads to a change in the angle of attack (slip) of the rocket and transverse overload, under the influence of which the rocket moves in the transverse direction, changing its angular coordinates. The changed angular coordinates of the missile and the target are fed to the coordinate blocks of the missile and the target, so the control loop is closed.

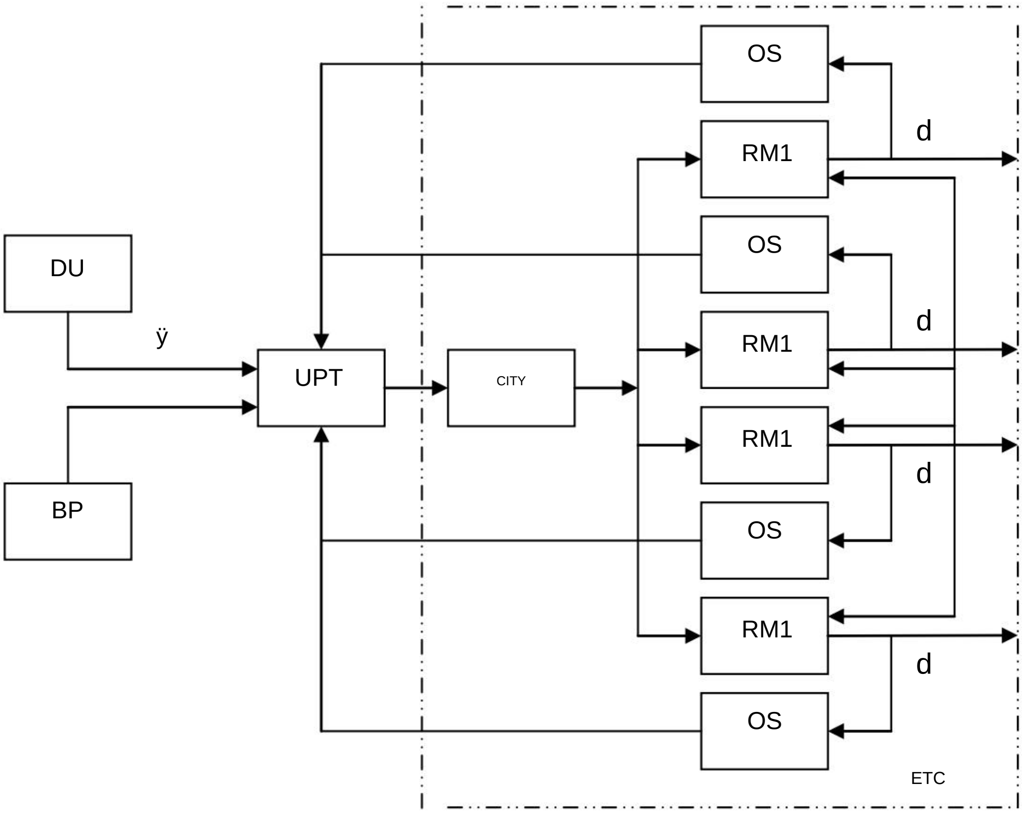
The command formed in each of the control paths is decomposed into one pair of rudders, ensuring the rotation of the rocket in the pitch and heading planes. In-flight current information At various angles of rotation of the rocket in pitch and heading, it enters the same declination paths from the angle sensors of the free gyroscopes. After 1.5…2 s after the beginning of the declination, upon command "Control" from the BRU, the autopilot switches from the declination mode to the control mode. In this case, the "Control" command is blocked, turns off the declination path and connects the control path to the steering machines.

In the control mode, the autopilot fulfills the commands K1 and K2 coming from the BRU according to a given algorithm. At the same time, the restriction of signals to steering machines at the level of 15º of rudder deflection is organized. Switching of the limitation level is carried out by the command "KPO" ("Switching the limitation of the rudder deflection angle") from the signaling device for pressure drop in the gas generator of the declination system (or by the command "Control" from the BRU).

At the end of the control section, when the rocket speed drops to 400 ... 600 m / s, the "KP" command transmitted from the missile guidance station through the BRU switches the autopilot gains.

During the entire time of inclination and control, the autopilot ensures the stabilization of the rocket relative to three mutually perpendicular connected axes. Stabilization is carried out according to information coming from three angular acceleration sensors, the sensitivity axes of which are located along the corresponding coupled axes of the rocket.

During the entire time, the rocket is stabilized by the angle of roll. Stabilization is carried out by the autopilot bank channel (channel 3) according to information from the free gyroscope bank angle sensor. The signal generated in the roll channel is decomposed into all four steering machines, parrying the rocket's movements relative to the longitudinal axis (Fig. 25).



Rice. Fig. 25. Structural diagram of the autopilot roll stabilization channel (see Fig. 24)

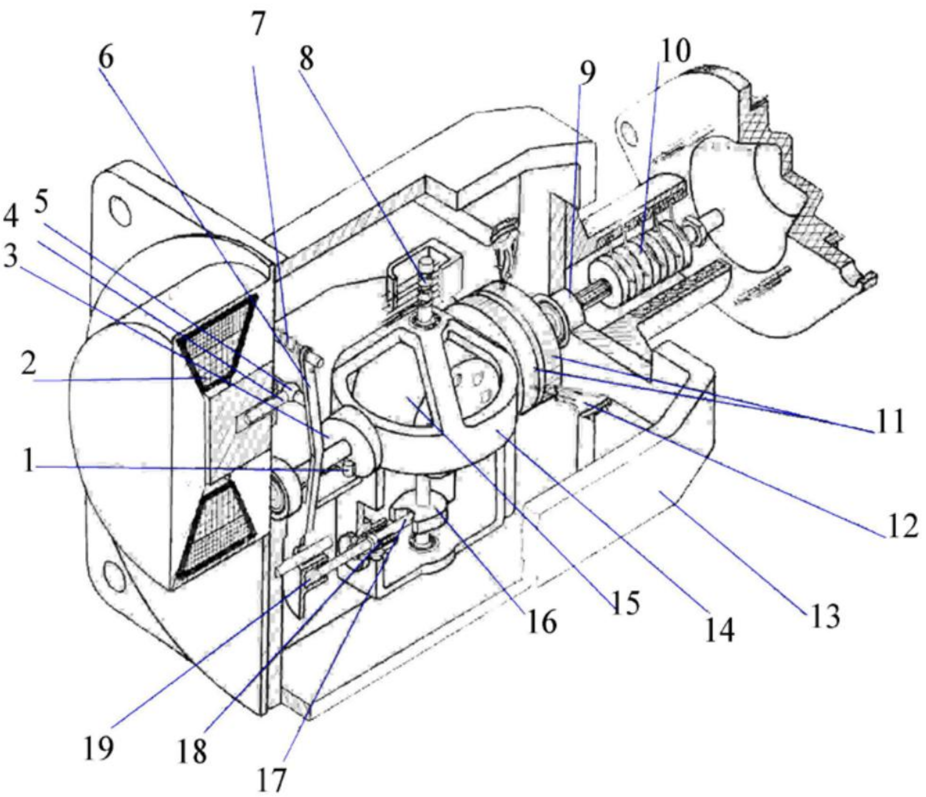
Stabilization of the rocket relative to the center of mass (relative to the transverse axes *O1* and *O2)* is reduced to the introduction of additional artificial damping of the rocket using the autopilot. This is necessary to meet the requirements for the quality of transient processes when processing control commands, i.e. to limit overshoot in terms of angles of attack and slip. Although the missile is statically stable, its own damping is insufficient and transients during the processing of control commands would have unacceptable oscillation and overshoot along the mentioned angles. To artificially increase the damping of the rocket, the autopilot provides for negative feedback on the angular velocity of the rocket. The introduction of this feedback forms a closed stabilization loop. In view of the fact that during a controlled flight of a rocket there is always a dynamic error in the control loop (missile lag behind the kinematic trajectory), a signal for its compensation is introduced into the loop for all guidance methods. The dynamic error compensation circuit is not included in the closed control loop. It forms an additional command that changes the curvature of the rocket's flight path in the direction of decreasing linear deviations relative to the kinematic trajectory.

The sensing elements of the autopilot are free gyroscopes, angular acceleration sensors (RCS) and linear acceleration sensors. *Free gyroscopes* actually perform the functions of the autopilot's calculating device. They are designed to convert control radio commands from a conditionally immobile coordinate system into control commands (voltages) of a coupled coordinate system. The property of a free gyroscope is used to keep the position of the rotor axis in space unchanged. The voltages taken from the brushes of the functional potentiometers are free gyroscopes are distributed between the channels so that the control voltage UNI is supplied to the input of the direct current amplifier (DCA) of channel *I* , and the voltage UNII is applied to the input of channel *II* , respectively. Thus, the UPTs sum up the signals of the remote control unit and free gyroscopes, compare the resulting control signal with the signal of the feedback potentiometer of the steering machine, and generate an error signal to actuate the gas distributor through the power supply channels of the RM.

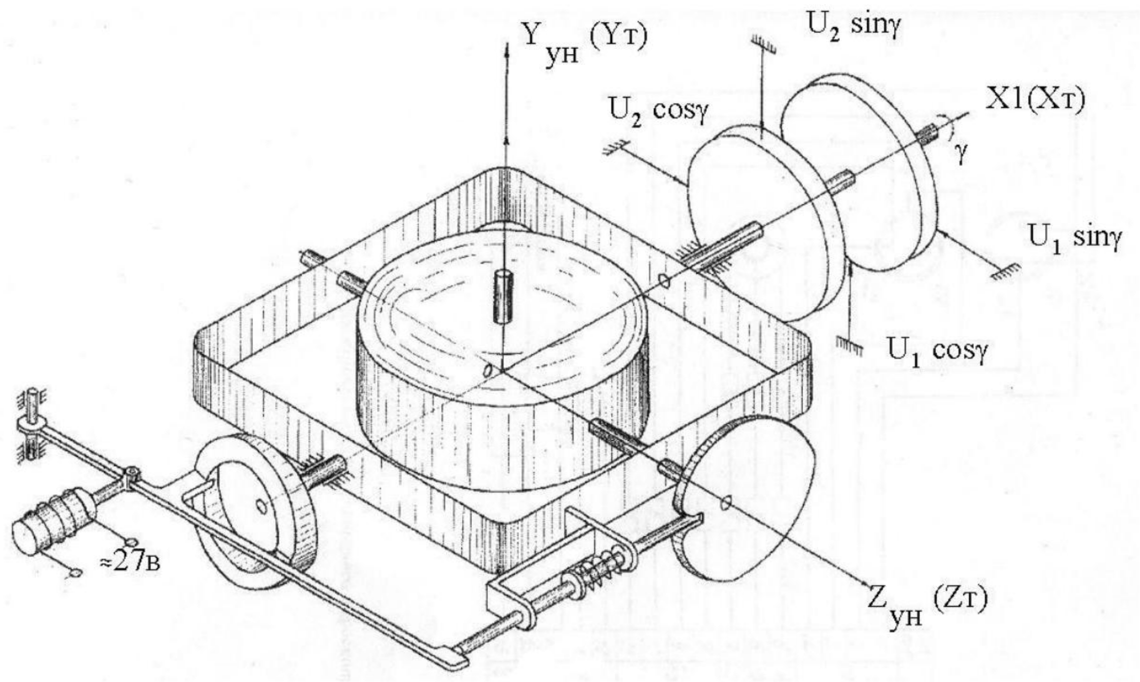
The steering drive forms two closed circuits of the servo systems with the UPT: the drive circuit itself and the zeroing system circuit. The drive circuit is designed to move the rocket rudders in accordance with the resulting control signal, the zeroing system circuit is designed to compensate for zero errors in the amplifier and the jet relay of the gas distribution device.

The design and kinematic diagram of a free gyroscope are shown in fig. 26 and 27 electrical circuit of the autopilot - in fig. 28.

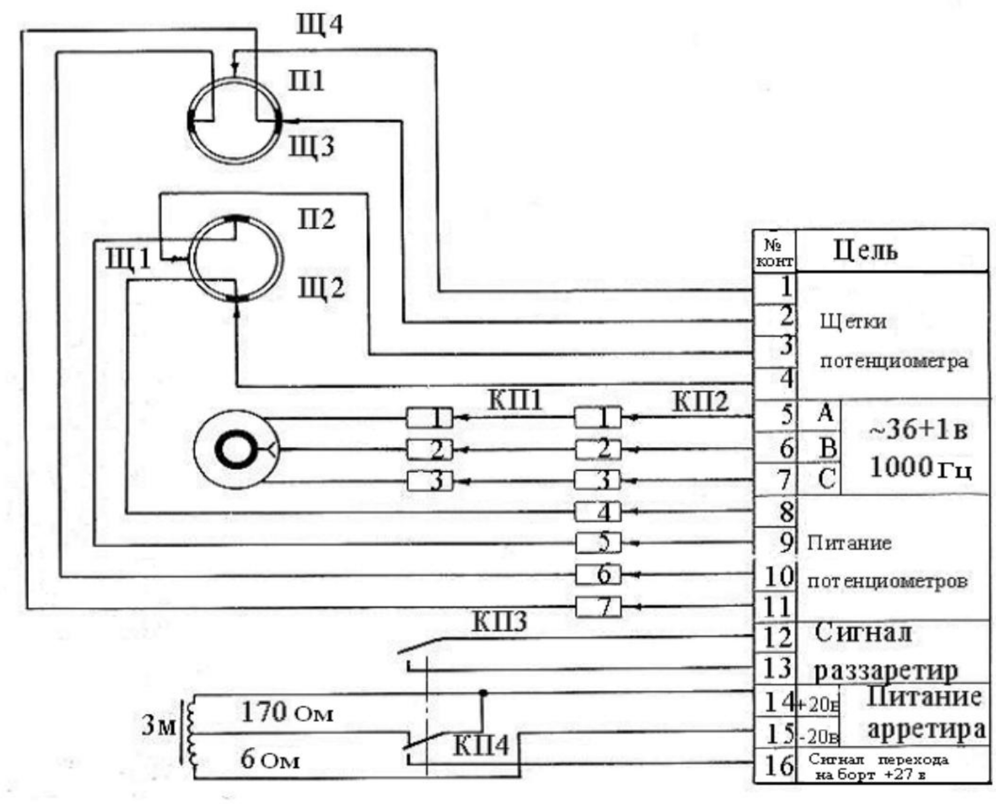
The main units of a free gyroscope are gyro unit *15,* outer frame *14,* arrester mechanism 16–19 , and potentiometric sensors *11.* The gyro unit uses a gyro motor, which is an asynchronous three-phase electric motor. The gyromotor is powered by alternating voltage (36 ±1) V (1000 ±100) Hz, which is supplied through the collector ring *10* on the axis of the outer frame (Fig. 26) and *8* on the axis of the inner frame. The number of revolutions of the gyro motor is not less than 51000 rpm. The maximum angle of rotation of the inner frame *15,* mounted on the outer frame, from stop to stop ± 80 ÷ 85 º. Ready time (with afterburner) no more than 10 s. To ensure the initial mutual position of the gyroscope frames until the rocket launch, a caging mechanism is provided, the device of which is clear from the figure. The gyroscope is locked when electromagnet 2 is de-energized.



Rice. 26. The design of a free gyroscope: *1* - roller; *2* – electromagnet coil; *3* - cam; *4* - movable anchor; *5* - earring; *6* - lever; *7* - spring; *8* – collector ring on the axis of the inner frame; *9* - bearing; *10* - collector ring on the axis of the outer frame; *11* - potentiometer; *12* - contact brush; *13* - body; *14* - outer frame; *15* - inner frame; *16* – profiling cam on the axis of the inner frame; *17* - pusher; *18* - spring; *19* - catcher

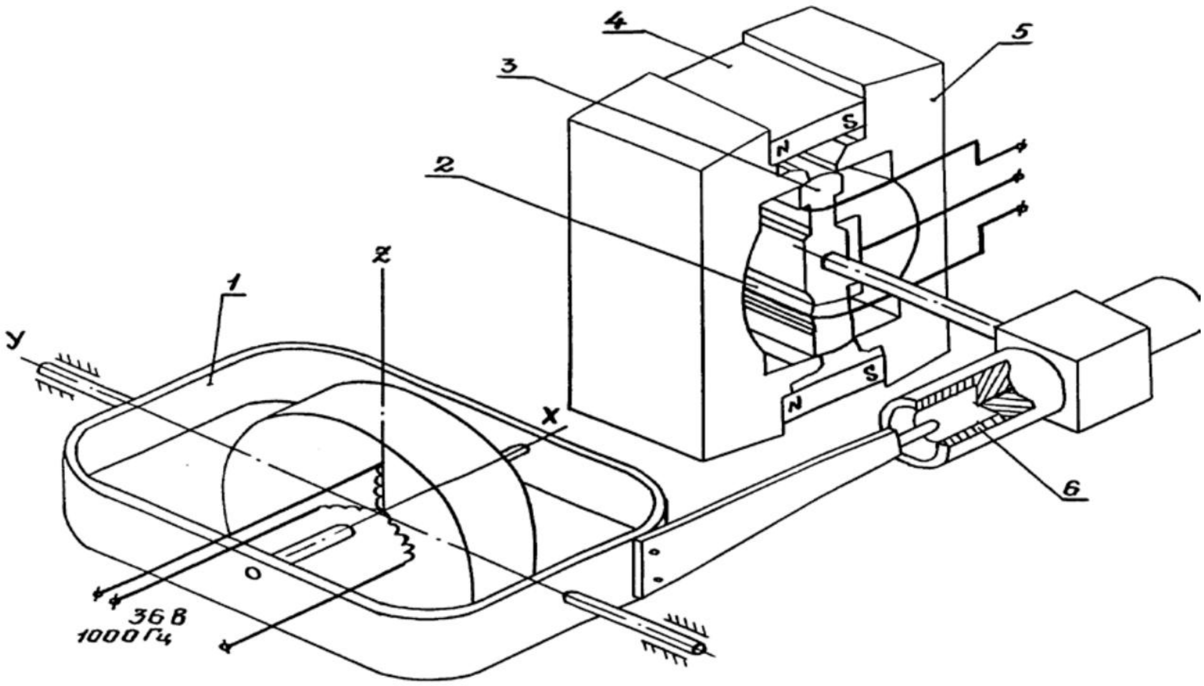


Rice. 27. Kinematic diagram of a free gyroscope



Rice. 28. Electric circuit of a free gyroscope

Angular acceleration *sensors* (velocity gyroscopes, Fig. 29) are designed to measure the angular accelerations of the rocket relative to the associated coordinate system and generate signals in the form of DC voltage. These voltages correspond to the values of the angular acceleration component about each axis. The sensitive element of the sensor is a two-degree gyroscope. When the rocket is rotated relative to the axis of sensitivity of the sensor, the precessional movement of the gyro unit occurs at a speed proportional to the angular acceleration
niyu rocket.

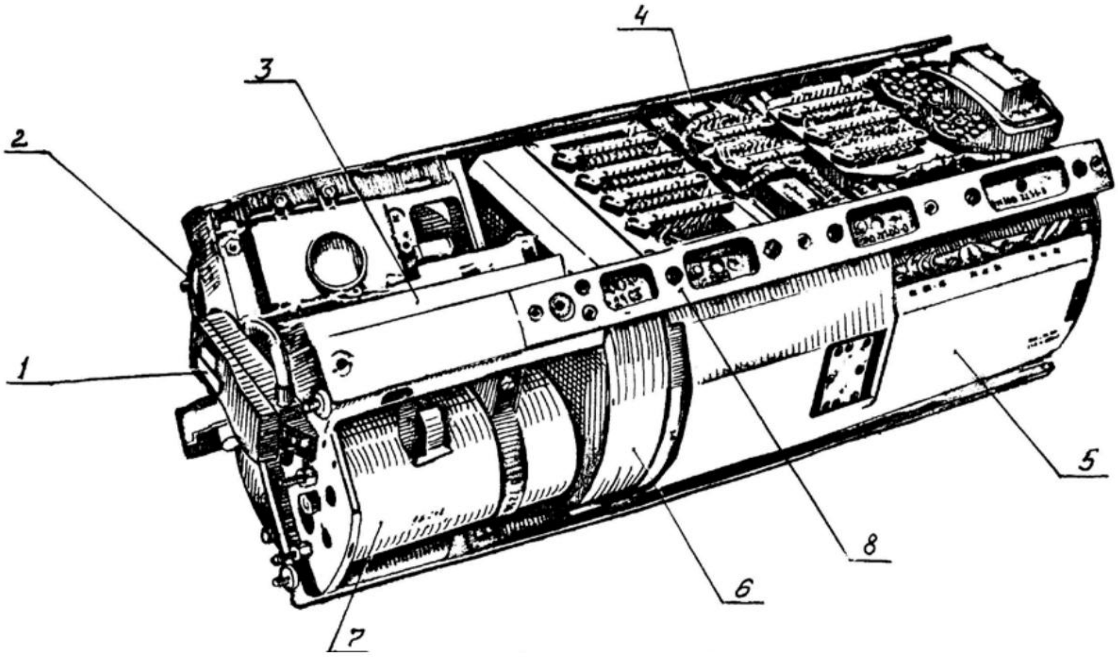


Rice. 29. High-speed gyroscope (angular acceleration sensor): *1* - gyroscope, *2* - coil, *3* - rotor, *4* - magnet, *5* - magnetic core, *6* - drive gear

The linear acceleration sensor of the autopilot is designed to measure linear accelerations and generate a signal in the form of a DC voltage, the value of which is proportional to the linear acceleration acting in the direction of the measuring axis. The principle of operation of the sensor is based on the property of a physical pendulum to be set in the direction of the resulting forces acting on it in the direction of the measuring axis. The sensor is a design that combines the electromechanical and electronic parts of the device in one housing. The electromechanical part is a pendulum of two cylindrical weights of different masses on a rocker arm. The deflection angle of the pendulum is limited by stops.

The DC amplifier is designed to generate a control signal and amplify its power. The control signals in the form of DC voltages taken from the brushes of the functional potentiometers of free gyroscopes are fed to the input of the amplifiers of channels *I* and *II .* At the input of the UPT, the control signal is added to the stabilization signal generated by the angular acceleration sensor, and the resulting control signal is compared with the feedback signal of the steering gear. The received signal is amplified in power and fed into the windings of the gas distributor.

The general view of the control unit is shown in fig. 30 and 14.



Rice. 30. Hardware monoblock: *1* - delay unit, *2* - electric machine converter, *3* - command block, *4* - radio fuse receiver, *5* - on-board radio control equipment, *6* - autopilot, *7* - battery, *8* - stringer

Questions for self-control in section 4

1. What should the onboard radio control equipment do? 2. What functions does the onboard radio control equipment (BRU) perform? 3. What commands does the command transfer station (CTS) send? 4. What tasks does the onboard radio control equipment solve by executing the SPK commands? 5. List the main blocks of onboard equipment. 6. Why are power supply voltages used for BRU operation? 7. What is the meaning of using levels logical “1” or logical “0”? 8. How does the BRU function in the "Preparation" mode along the "Record" chain? 9. What kind of BRU operates in the “Standby” mode? 10. What BRU functions in the “Start” mode? 11. What functions does the missile sighting station (SVR) perform? 12. Purpose and modes of operation of the onboard radio transponder. 13. How is one of the two receiving antennas determined in flight in the BRU? 14. What does the synchronous and asynchronous mode of operation of the BRU elements mean? 15. When is the "Control" command issued? 16. What signals does the DCU give out during the flight? 17. How does the BRU work in case of a radio link failure? 18. The meaning of using logical "0" and "1". 19. When is a command issued to self-destruct a rocket? 20. Purpose of the command block. How are teams formed? 21. What functions does the autopilot perform? 22. What is included in the autopilot? 23. Why are there two linear acceleration sensors and three angular acceleration sensors in the autopilot?

rhenium and three free gyroscopes?

24. How is the loss of dynamic stability of the rocket prevented after leaving the TPK in the vertical leg of the flight? 25. When does the rudder gear zeroing take place? 26. What is the orientation of the aerodynamic planes (rudders and wings) of the rocket in flight? 27. How are control commands formed in the declination section?

28. How are control commands implemented in the declination section?
29. How is the restriction on the angle of rotation of the rudders on the initial part of the declination section removed?
30. Autopilot functions in control mode.
31. In what coordinate system are rocket control commands formed?
32. In what coordinate system are the rocket control commands implemented?
33. How is the roll stabilization of the rocket?
34. What is a dynamic trajectory?
35. What is a kinematic trajectory?
36. What is the essence of aiming a missile at a target?
37. What is a dynamic error?
38. Appointment of free gyroscopes.
39. The device of a free gyroscope.
40. Why is the maximum rotation angle of the inner frame of the gyroscope limited?
41. Purpose of the angular acceleration sensor.
42. The principle of operation of the angular acceleration sensor.
43. Purpose and device of the linear acceleration sensor in the autopilot.

5. COMBAT EQUIPMENT

5.1. radio fuse

The radio fuse (RV) 9E337 is an integral part of the onboard missile control equipment and is a radar device designed to generate and issue commands to the PIM of the warhead detonation pulse at a point that provides maximum target coverage with striking elements (fragments) of the warhead.

The radio fuse is a small-sized non-contact radar active pulse fuse and operates in the following combat modes: NLTs (low-flying target), NVTs (surface target), PP (passive interference) and standard.

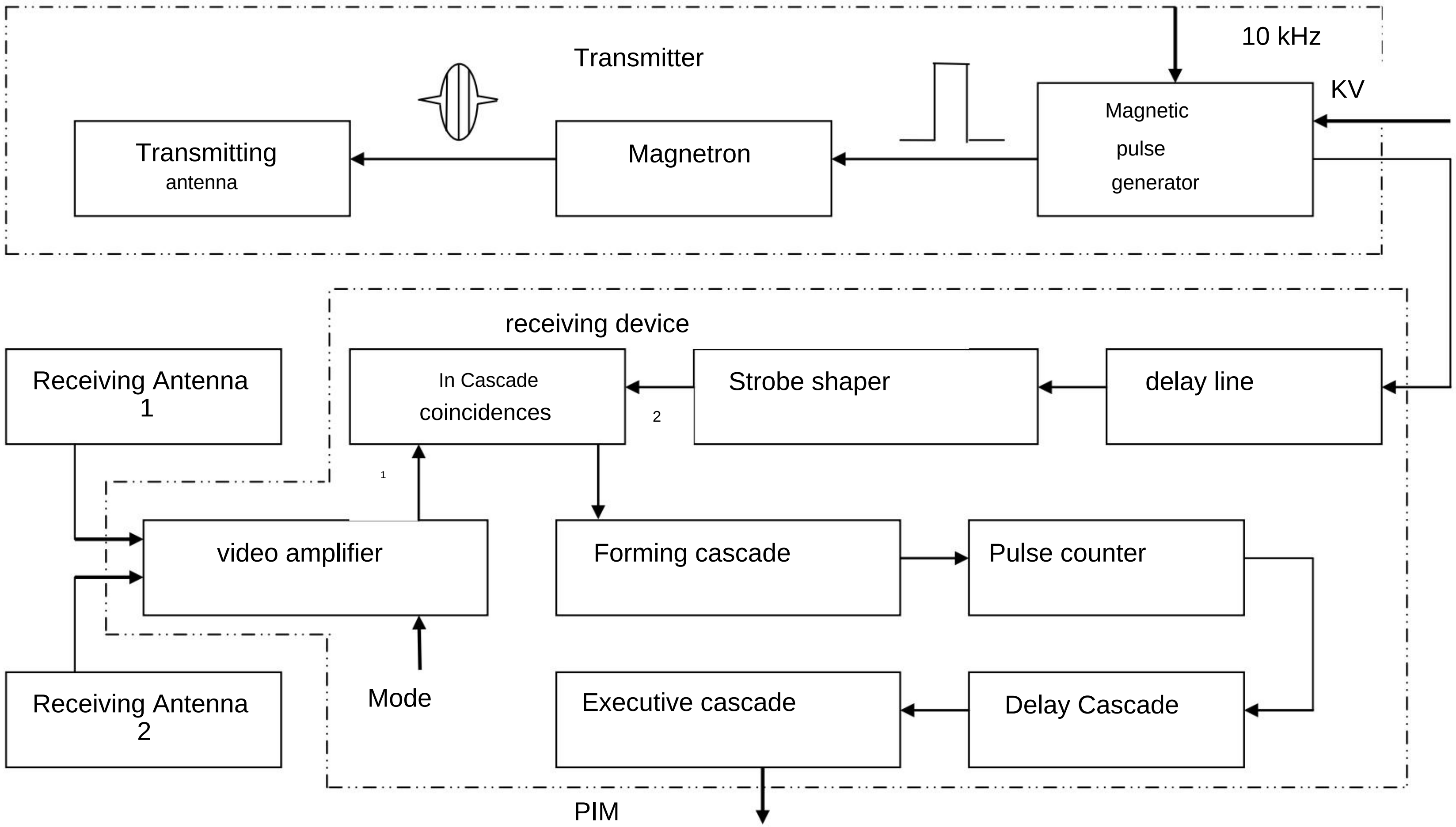
The functional diagram of the RW is shown in fig. 31 [16,17]. It includes an antenna stem, transmitting and receiving devices.

The RV antenna system consists of a transmitting disk-cone antenna installed under the nose cone and two receiving slotted antennas installed in niches of the body of the third compartment on the right and left sides of the missile. Such an arrangement of antennas aligns the resulting radiation pattern in a plane normal to the rocket axis and provides the required no isolation between the receiving and transmitting paths.

The RV transmitter consists of a transmitting antenna, a magnetron and a magnetic modulator (magnetic pulse generator). The latter generates rectangular voltage video pulses with a duration of about 0.1 ÿs with a repetition rate of 10 kHz. These voltages are the supply voltage for the magnetron generating high-frequency radio pulses sy and directing them to a transmitting antenna, which radiates them into space.

In addition to the probing microwave pulse, the transmitter generates RF pulses (SI) synchronizing the operation.

The receiving device contains a microwave unit with an amplifier and a detector, a video amplifier and an information processing unit. The information processing unit, depending on the specified mode of operation of the RT (NLC mode, PP mode, normal mode), controls the operation of the receiving device, if necessary, automatically limiting the range of the RT and coarsening the sensitivity of the receiving path. Due to this, the selection of signals reflected from the target against the background of the earth's surface, as well as in the presence of interference, is carried out. The processing unit also counts the pulses reflected from the target. The high-frequency radio pulses reflected from the target are picked up by antennas *1* and *2* and enter the detector sections structurally aligned with the antennas (see Fig. 31).



Rice. 31. Functional diagram of RV

The video pulses received at the output of the detector sections are amplified by a video amplifier and fed to the input of the first coincidence stage. Gating pulses from the gate shaper are fed to the input of the second stage. Gating pulses are formed from synchronizing pulses coming from the magnetic pulse generator through the delay line. When the strobe and video pulses coincide in time at the coincidence stage, a pulse is generated from it to start the shaping stage, which generates pulses normalized in amplitude and duration, which arrive at the counter.

Gating in RT is provided for range selection and provision of decoupling from the earth's surface.

Time selection for the accumulation of information (counting a certain number of reflected pulses) increases noise immunity with respect to random noise bursts and passive noise. To provide additional decoupling between the transmitting and receiving antennas, to correct the area of operation of the radio waves on small misses and to increase the noise immunity to passive noise, the software sensitivity adjustment is provided in the radio radio. To increase noise immunity to active interference, the video amplifier has a coarsening chain.

To effectively hit the target, it is necessary to coordinate the area of operation of the RV with the area of expansion of the main mass (80 ... 90%) of the warhead fragments. The area of operation of the RT is a part of the space in which the conditional centers of targets may be at the time of its operation. Coordination of the region of operation of the RV with the region of fragmentation is carried out by delaying the impulse to detonate the warhead, depending on the relative velocity between the missile and the target. Information about the specified speed is entered into the RT by the commands of the KOS.

Before the launch of the rocket, commands are issued from the equipment of the launch automation on the RV, pouring one of the modes of its operation.

During a controlled flight, the ground control station determines and transmits to the missile the rocket and target relative velocity (RVR) commands that arrive at the RV and sets a certain delay between the moment the RV is triggered and the warhead is detonated.

When the missile approaches the target at a predetermined distance, the RV transmitter is turned on by the command to control the cocking of the RV (KUV) coming from the onboard radio control equipment. Probing impulses of the RW transmitter irradiate the target.

By the arming radio command (KV), following the command of the ECU, the information processing unit is turned on, which, taking into account the mode of operation of the RV, analyzes the pulses reflected from the target and, upon accumulation of a certain number of them, issues an actuation pulse.

5.2. Safety actuator

The safety-actuating mechanism (PIM) 9E134 is designed for:

– to ensure reliable protection against accidental explosion of the loaded missile warhead at all stages of storage, transportation and operation;

- to prevent the detonation of the warhead during launch and in flight until commands are received KUV and KV;

- for issuing a detonation impulse to detonate the warhead of a rocket on command from a radio fuse or from a control unit;

- for self-destruction of the rocket in flight when the radio fuse fails on the target.

PIM operation is possible only after the safety stages are removed during the flight of the rocket and its cocking.

PIM has three stages of protection, the removal of which requires the presence of the following factors:

– launching and entering the mode of the onboard chemical current source, from which the PIM is powered; - starting the engine - the presence of pressure in its combustion chamber, from which, using the signal the pressure analyzer closes the contacts in the cocking circuit of the PIM;

- axial overload during the rocket flight (immediately after launch) of at least 19 with a duration of at least 1 s. Due to the action of the inertial force, the locking of the moving parts of the PIM on the line of the fire circuit is removed and additional contacts are closed in the circuit introductions.

During the launch cycle, the HIT of the rocket is launched, and when it enters the mode, it becomes possible to supply voltage to the cocking circuit of the PIM. This removes the first stage of the PIM protection (this circuit is additionally opened by the pressure switch in the engine and the PIM inertial contactor). During the ejection of the rocket, the PIM is in its initial state, since the circuit for supplying voltage to the PIM is open by the pressure indicator in the engine.

When the engine is started and the pressure in the combustion chamber rises, the pressure alarm is activated, closing the contacts for outputting voltage from the HIT to the PIM cocking circuit. The second stage of its protection is removed.

Under the action of axial acceleration with the engine running for at least 1 s, the inertial contactor closes the PIM arming circuit. The third stage of protection is removed, the final cocking of the PIM takes place. If the axial acceleration lasts less than 1 s, the removal of the third stage of protection and the final cocking of the fuse do not occur.

The operation of the PIM and, as a result, the detonation of the warhead occurs in two cases:

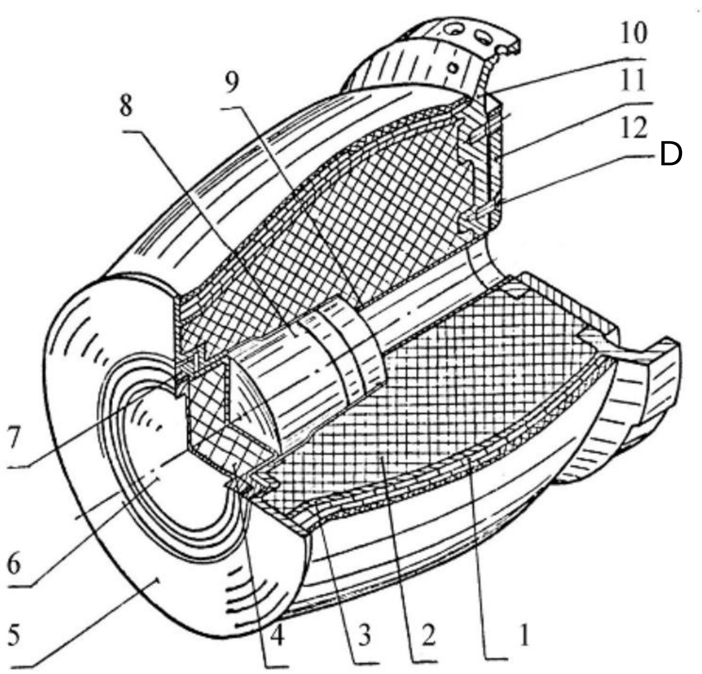
- near the target on the signal "Operation" - to hit the target;
- in case of a miss (failure to receive a signal from the RV) according to the electrical signal "Liquidation" from the BRU - to eliminate the missile.

5.3. Warhead

The high-explosive fragmentation warhead as part of the missile's combat equipment provides destruction of enemy air attack means by fragmentation submunitions, and near the target also by high-explosive impact.

The warhead (Fig. 32) consists of a body, a fragmentation shell, an explosive charge (HE) and an additional detonator. The case is a welded structure consisting of a thin-walled outer shell *3* and two flanges *5* and *10.* Along the axis of the warhead, inside the explosive charge, the case has a cavity formed by the inner shell *9 of* stepped cylindrical shape. From the large diameter side, a PIM and an additional detonator (block 4, nut 7, cover 6) are installed in the cavity, which is screwed into flange 5 on the thread.

The fragmentation shell is placed on shell *3* of the warhead housing between flanges *5* and *10.* It consists of striking elements 1 made of a high density alloy. Electrical communications from the PIM connector are output through the "D" cavity outside the warhead.



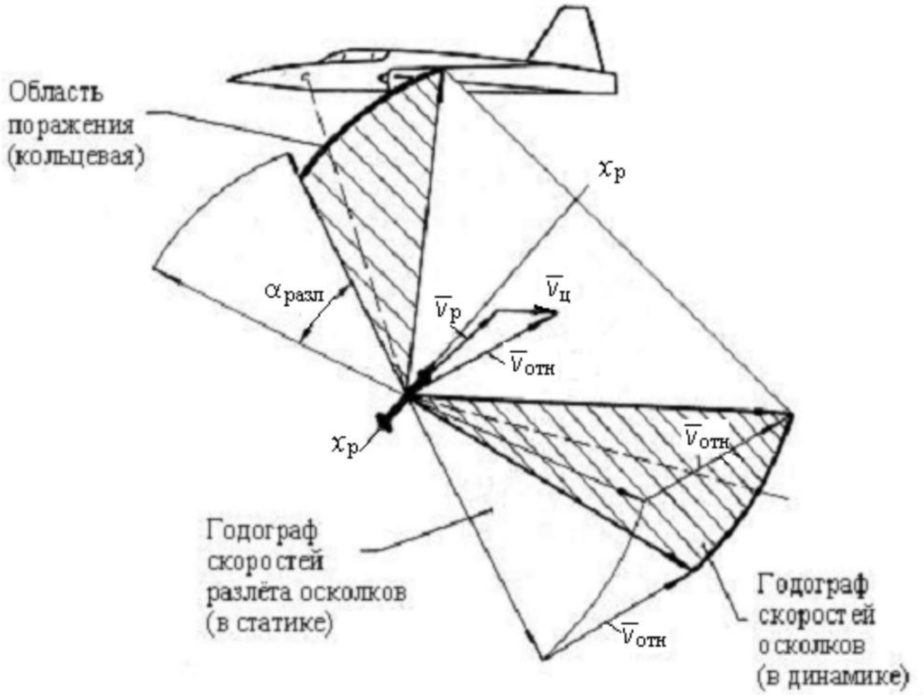
Rice. 32. Warhead: *1* - striking elements; *2* - explosive charge; 3, *9* - shell; 4 - checker; 5, *10* - flange; 6, *11* - cover; *7* - nut; *8* - PIM; *12* - screw

When the initiating pulse from the PIM is applied to the additional detonator, the checker *4* is triggered and causes the detonation of the bursting charge 2. The resulting shock wave and detonation products break the thin-walled shell *3 of* the body and provide the throwing of striking elements. In the transverse plane, a circular fragmentation field is formed with specified characteristics

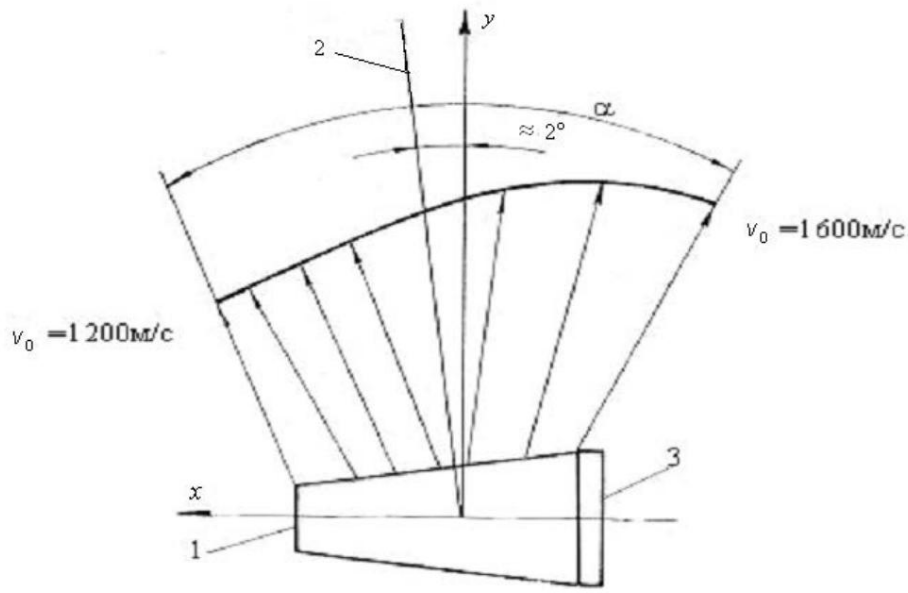
ristikami, hitting the target.

The angle of expansion of striking elements in the longitudinal plane depends on the shape (curvature) of the shell *3 of* the body of the warhead, which determines the shape of the explosive charge and the fragmentation shell. The value of this angle is chosen from the condition of covering the target with a stream of submunitions in various conditions of the meeting of the missile with the target, also taking into account the angles of operation of the missile launcher.

The kinematic scheme of covering the target with the affected area of the warhead is shown in fig. 33, race the determination of the initial velocities of fragments according to the angle of expansion (in static conditions) is shown in fig. 34.

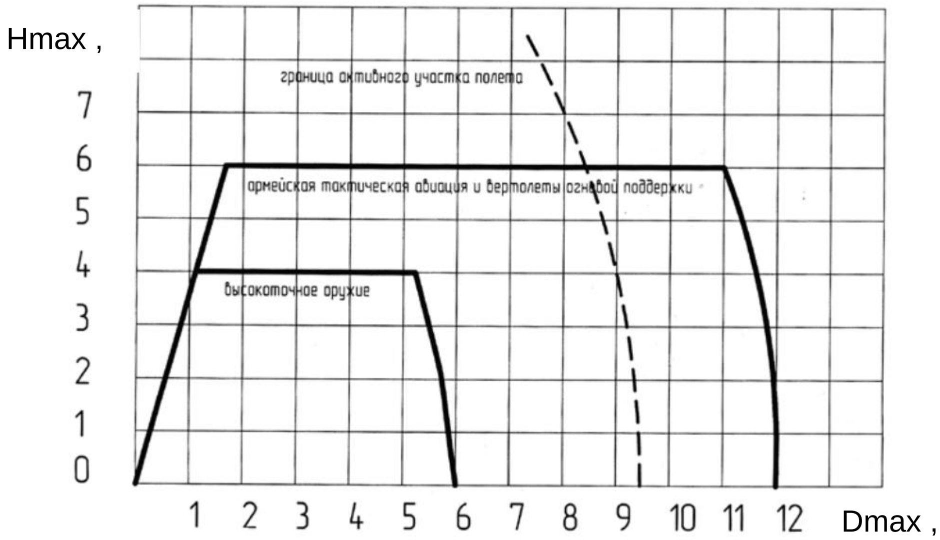


Rice. 33. Kinematic scheme of covering the target with the area of destruction of the warhead: - - - - - line of operation of the radio fuse; xp is the longitudinal axis of the rocket; ÿspread is the angle of fragments expansion; $\bar{v}_r, \bar{v}_c, \bar{v}_{otn}$ - rocket speed, target and relative speed



Rice. 34. Distribution of the initial velocities of fragments over the angle of expansion (in static conditions):
1 - front end; *2* - the direction of expansion of the main mass of fragments; *3* - rear end

The effectiveness of a missile, determined by the damaging effect of the warhead and the dispersal of its point of detonation relative to the target, should be high not only when impacting weakly protected targets, such as airplanes and helicopters, but also when impacting high-precision weapons, which often have high durability. A characteristic view of the affected areas of various targets is shown in fig. 35.



Rice. 35. The zone of destruction of various targets

Questions for self-control in section 5

1. What functions are assigned to a radio fuse?
2. When and on what command does the radio fuse begin to irradiate the target?
3. How is the warhead demolition team formed?
4. List the design solutions that ensure that the target is covered with a stream of hitting elements in various conditions of the meeting of the missile with the target.
5. In what modes does the radio fuse work?
6. The order of operation of the radio fuse.
7. Components of a radio fuse and their purpose.
8. What are the main elements of the RV transmitter? 9. What is a magnetron for and how does it work?
10. Components of the radio fuse receiver and their purpose.
11. What functions does the information processing unit of the receiving device of the radio explosion perform? calf?
12. Where do the pulses come from to the counter of the information processing unit of the receiving device radio fuse?
13. How do you understand the phrase “coincidence in time of strobe and video pulses on the cascade coincidences?
14. Why does the radio fuse provide software adjustment of the sensitivity and coarsening point?
15. Due to what the maximum efficiency of the warhead in the area is achieved goals?
16. What determines the area of operation of a radio fuse?
17. How is coordination of the operation area of the radio fuse with the expansion zone achieved? splinters?
18. How is the increase in the noise immunity of the RT achieved?
19. What is the purpose of the safety-actuator (PIM)? 20. What functions does PIM perform? 21. When and on what command is the PIM activated?

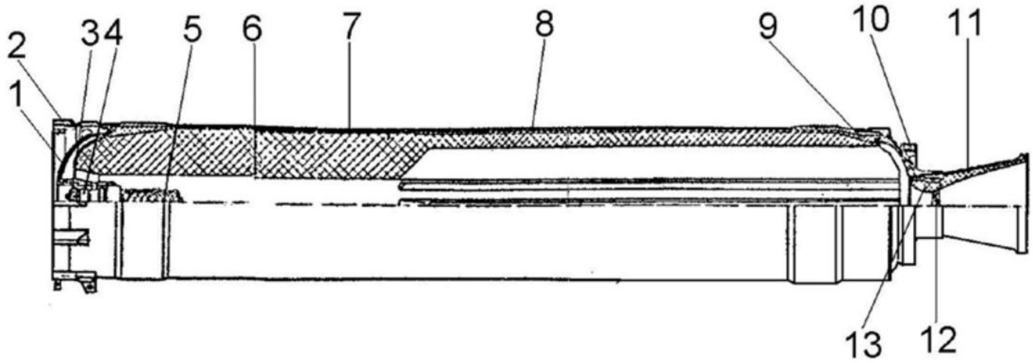
22. List the conditions under which the protection stages are removed in the PIM.
23. How is the first stage of protection removed in PIM?
24. How is the second stage of protection removed in PIM?
25. How is the third stage of protection removed in PIM?
26. When does PIM work?
27. Name the conditions necessary and sufficient to hit the target. 28. List the design solutions that ensure that the target is covered by a stream of hit elements in various conditions of the meeting of the missile with the target.
29. How to build a kill zone for any target?

6. Rocket engine

The rocket engine (Fig. 36) is a dual-mode single-chamber rocket solid fuel engine (RDTT), which consists of:

- housing, including a cylindrical part 7, front bottom 1, rear bottom *9* and nozzle block *11* with insert *13* and plug *12;*

– solid propellant charge *6* – single-channel mixed propellant cartridge having slot cuts on the side of the engine nozzle. The presence of eight slots makes it possible to significantly increase the fuel combustion surface and ensure the starting mode of engine operation. In the marching mode, after the charge burns out in the zone of slots, combustion is carried out only on the surfaces of a single-channel checker;



Rice. 36. Rocket engine: *1* - front bottom with a heat-shielding bowl; *2* - power frame; *3* - pressure signaling device; *4* - squibs; *5* - igniter; *6* - charge of solid fuel; *7* - body; *8* - heat-shielding coating; *9* - rear bottom with a heat-shielding bowl; *10* - landing belt; *11* - nozzle block; *12* - plug; *13* - insert

- igniter *5* with two squibs for its ignition and pressure indicator *3* in the combustion chamber. All elements are located on the front bottom of the engine housing. The signaling device is used in the system of protection of military equipment for issuing a command to cock a radio fuse. The second squib serves to duplicate the engine start. The backup squib fires one second after the engine is started, providing ignition of the igniter in the event of failure of the first squib.

The front and rear bottoms (elliptical shape) of the body are made of high-strength steel. On steel type KVN with 2 ÿ 190 = kg/mm the outer cylindrical part of the bottoms, special thrust threads are cut and flanges are machined, with the help of which, when screwing the bottom, they are centered relative to the front frame and the thickening of the rear end of the cylindrical part of the body.

The cylindrical part of the body is a thin-walled cylinder 7 made of high-strength sheet steel, to the front end of which a power frame 2 is welded. Ten bosses are placed on the power frame and a special thrust thread is cut for screwing the front bottom. In the bosses, made as a single unit with the frame,
threaded holes are cut, and studs are installed in them for connection with the instrument compartment of the rocket. In the thickening of the cylindrical part of the rear end, a special

thrust thread for screwing in the nozzle block, drilled holes for docking with the wing block compartment.

A cylindrical seat belt *10 is* welded to the rear bottom , on which the bearing of the fifth compartment is installed, and a cylindrical nozzle, in which a thread is cut for
nozzle screwing.

The tightness of the internal cavity of the engine housing during storage and operation is ensured by pressing rubber gaskets between the cylindrical part and the bottoms. Gaskets are pressed by the front bottom and nozzle block during assembly. The junction of the block igniter - squibs is sealed with a copper gasket.

From the inside, a rubber bag is glued onto the cylindrical body, which plays the role of a protective and fastening layer *8* between the engine body and the charge. In the front and rear parts, the bag has thickenings in the form of cups, designed to provide the required stress-strain state of charge during temperature fluctuations.

The rear bottom has a seat for the bearing of the wing compartment and a thread on the outside.
bu for its fastening. On the inside, a thread is cut for installing the nozzle.

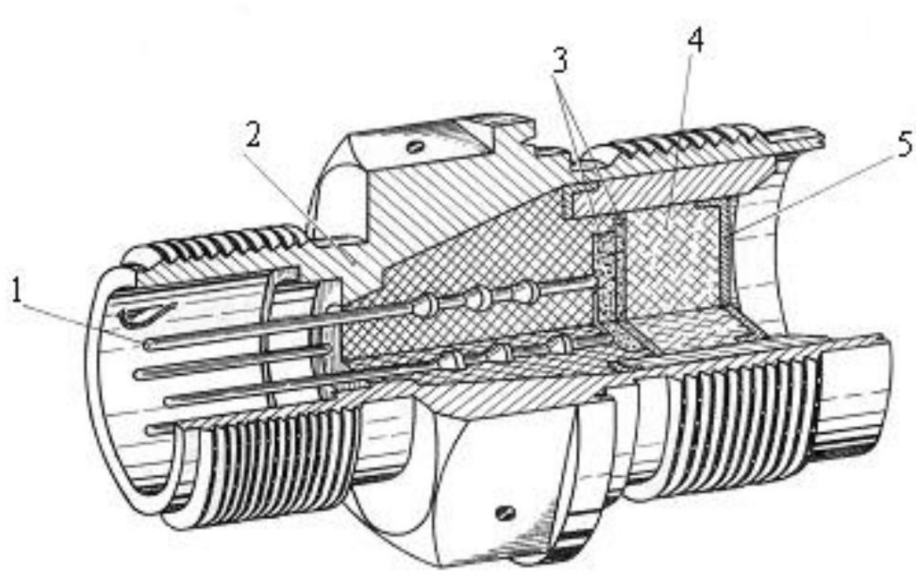
The nozzle consists of a body with a cylindrical threaded part and a conical outlet.
The critical section of the nozzle is formed by a nozzle insert screwed into the housing.

The graphite liner is glued into the internal cavity of the housing from the rear bottom side, the tightness of the joints during assembly of the nozzle block is ensured by rubber gaskets.
little

A glass is welded in the center of the front bottom, in which there are seats for installing squibs, as well as an internal thread for installing the igniter housing. A fitting is welded into the spherical part of the front bottom for installing a pressure alarm. The igniter consists of three cylindrical rods of solid fuel and a

sample of coarse-grained black powder, enclosed in aluminum cases and placed in a mesh housing.
The body of the igniter, fixed on the front bottom, partially enters the charge channel.

The igniter (Fig. 37) is designed to ignite the igniter. It consists of a body 2, a bottom 5, a sample of igniter composition 3, a sample of pyrotechnic composition 4, a connector for connecting a pyroprotective device, and an electric igniter 1 made in the form of a wire bridge. Reliable operation of the igniter is provided by two squibs.



Rice. 37. Igniter: *1* - electric igniter; *2* - body; *3* - igniter composition; *4* - pyrotechnic composition; *5* - bottom

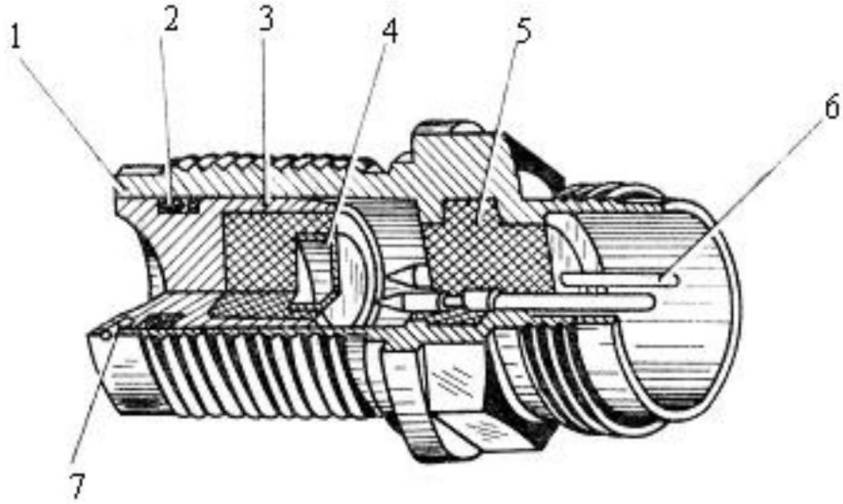
The operation of the engine begins from the moment the launch command is given through the electrical system circuit of the rocket in the form of a voltage current (+27 V) to the wire bridge of the squibs. Wire the bridge instantly heats up, causing ignition of the igniter composition of the squib, as a result of which its pyrotechnic composition also ignites. The resulting gases, breaking through to butt of the squib, ignite the main hitch of the igniter. The mass of gases formed and their thermal energy are sufficient to create the necessary conditions for the ignition of the fuel charge and its stable combustion. The combustion of the charge occurs along the internal channel, slots and ends. The pressure in the chamber in the starting mode is not more than 1.5 kPa. The thrust of the engine in the starting mode is ÿ3200 kgf. The engine operation time in the starting mode is ÿ 4 s [14], in the marching mode ÿ 8 s. Total engine running time ÿ12 s.

Questions for self-control in section 6

1. Give a description of the rocket engine.
2. Calculate the engine thrust in the starting and cruising modes of operation.
3. List the main elements that make up a rocket engine.
4. How is the dual-mode engine ensured?
5. How and by what command is a dual-mode solid propellant rocket launched? 6. How is the independence of the engine operation parameters from the ambient temperature ensured?
7. Draw a curve of change of pressure in the chamber of the engine in time.
8. How is the engine sealed?
9. How is the charge bonded to the case?
10. How is the required stress-strain state of charge ensured?
11. What is a charge igniter?
12. How does a squib work and how does it work?
13. For what purpose, along with a pressure indicator in a rocket, is a recession indicator used? pressure?

7. PRESSURE ALARM

The pressure alarm (Fig. 38) is a single-acting device and provides +27 V DC voltage to the PIM to remove the second stage of protection and to the command block to prepare the autopilot connection circuit when the pressure in the engine chamber is reached tel not less than 0.3 kPa [16]. The pressure signaling device consists of a steel case 1, in which is located an insulator *5* with two reinforced pin contacts *6* and steel piston 3.



Rice. 38. Pressure indicator: *1* - body; *2* - ring; *3* - piston; *4* - bottom; *5* - insulator; *6* - contact; *7* - pin

The piston has a brass bottom 4, isolated from the piston, and a sealing rubber-fluoroplastic ring 2. In the electrical system of the rocket, the signaling device is connected by pin contacts using a power outlet. In the initial (extreme left) position, the piston is held by a steel pin 7, while the contacts *6* are open. Under the influence of hot gases coming from the engine chamber on the piston, the pin is cut off and the piston moves to the extreme right position, closing *4* contacts with a brass bottom.

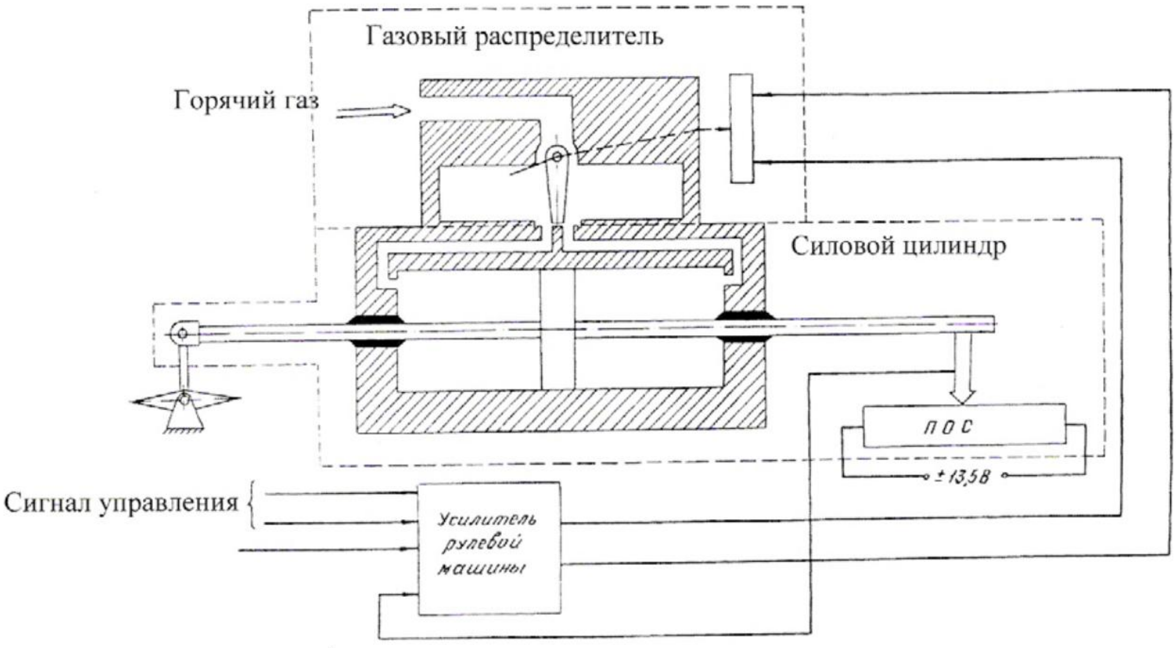
Questions for self-control in section 7.

1. *For what purpose, along with a pressure indicator in a rocket, is a recession indicator used?* *pressure?*
2. *How does the pressure alarm work?*

8. STEERING GEAR

The drive is designed to move the rudders in accordance with the resulting signals control and stabilization lamas generated in the autopilot circuit.

The operating principle of the drive can be seen from the electro-kinematic diagram shown in Fig. 39. A drive with a zeroing system consists of two circuits: the drive circuit itself and the zeroing circuit. Both circuits are formed on the basis of a common UPT and a gas distributor (jet relay).

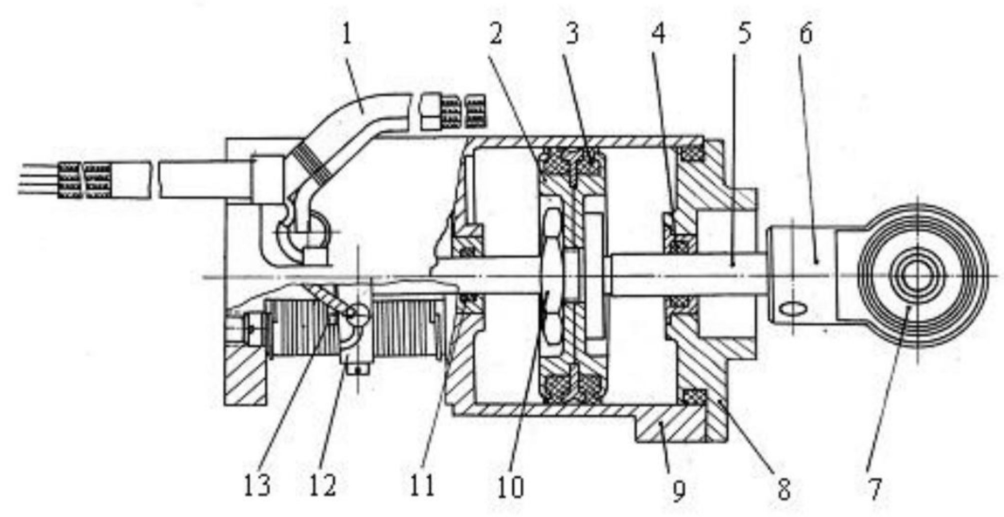


Rice. 39. Electrical diagram of the steering gear

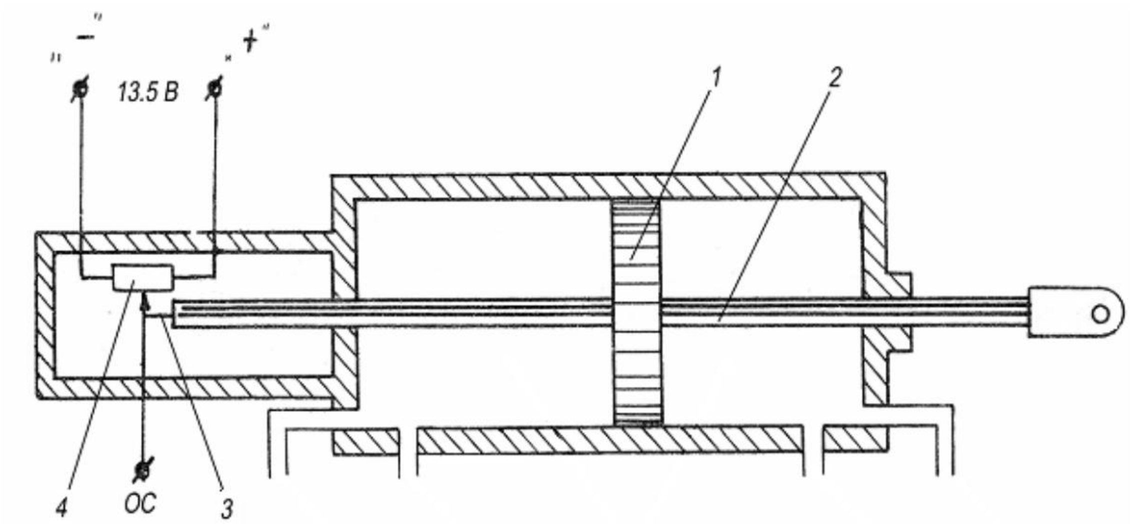
The drive circuit of each of the autopilot control channels includes UPT, gas limiter and power cylinder (steering gear) with feedback potentiometer.

The steering machine (Fig. 40.41), with the help of the energy of the compressed gas directed into its cavity, moves the executive body (rudders).

Feedback potentiometer (POS) generates a feedback signal in the form voltage proportional to the displacement of the steering machine rod (RM).



Rice. 40. Steering machine: *1* - electrical harness; *2* - disk; *3* - rubber cuff; *4.11* - sealing rings; *5* - stock; *6* - earring; *7* - bearing; *8* - cover; *9* - body; *10* - nut; *12* – feedback potentiometer; *13* - contact plate; *14* - potentiometer slider



Rice. 41. Electric circuit of the power cylinder: *1* - piston; *2* - stock; *3* - current collector; *4* - feedback potentiometer

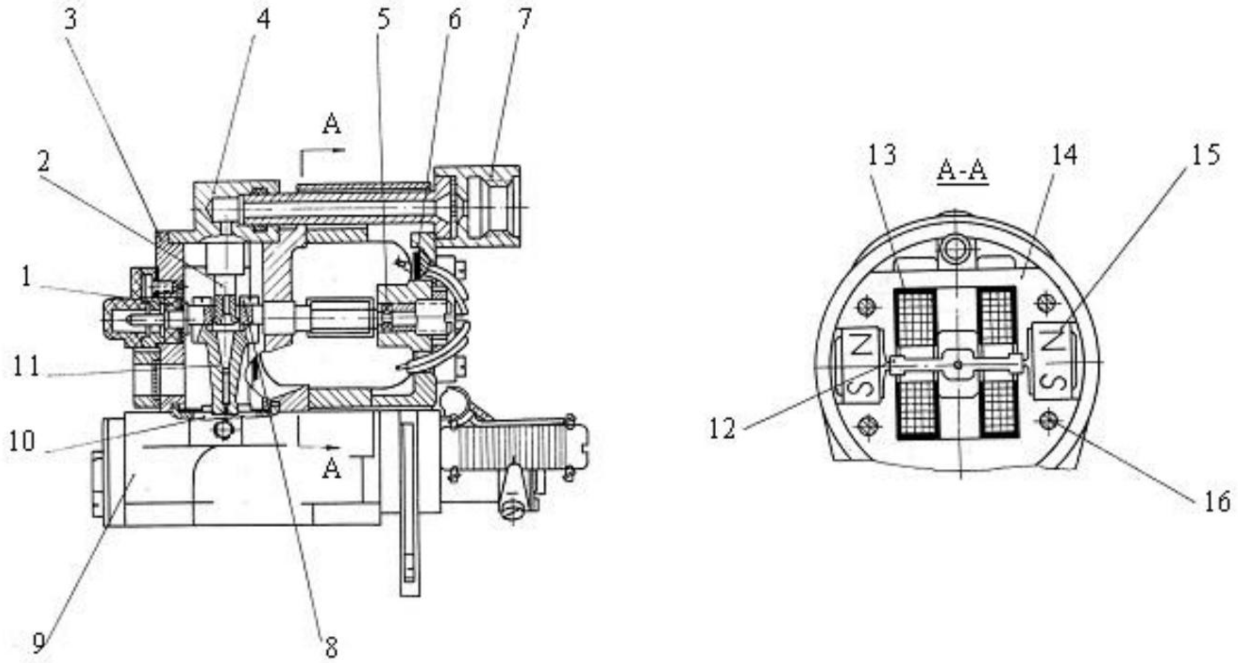
8.1. gas distributor

The gas distributor (Fig. 42) directs with the help of a rotary device in the cavity of the PM the amount of high-pressure gas that is required in accordance with the magnitude of the amplified DC signal. The polarity of the signal determines the direction of the gas flowing into either another cavity.

The gas distributor is designed to convert the steering circuit of the electrical signal coming from the UPT into a gas pressure drop proportional to this signal in the cavities of the power cylinder RM.

The high pressure gas supplied from the gas generator to the gas distributor enters the nozzle, and from it into two receiving holes, each of which communicates with the corresponding cavity of the power cylinder RM (Fig. 42).

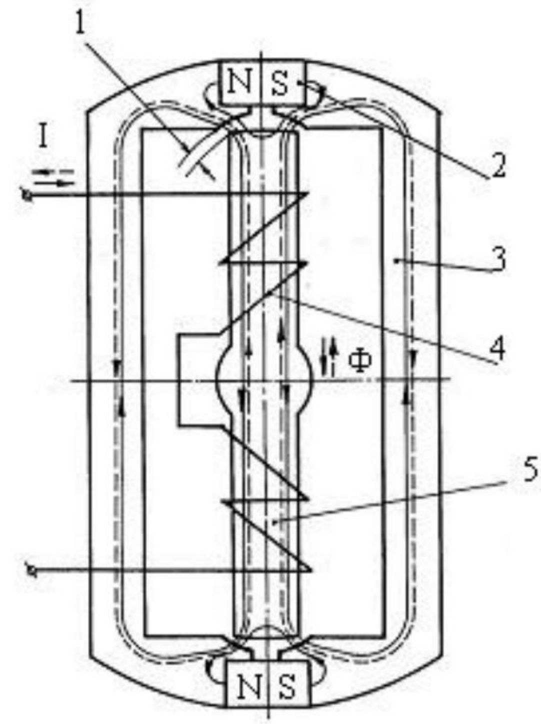
Nozzle *11* is rigidly connected to the armature of the electromagnetic rotary device of the gas valve and has the ability to rotate through an angle of ± 3º from the neutral position.



Rice. 42. The design of the gas distributor: 1.5 - bearings; *2* - nipple; *3* - body; 4.6 - flanges; *7* - bracket; *8* - screw; *9* - bracket; *10* - receiving part; *11* - nozzle; *12* - anchor; *13* - coil; *14* - magnetic circuit; *15* – permanent magnet; *16* - hairpin

The neutral position of the nozzle is considered to be when it is located symmetrically with respect to the receiving holes. In this case, when the gas flows out of the nozzle, the static pressures p1 and p2 are equal in the cavities of the power cylinder. Equality is violated if the nozzle deviates from the neutral position. The redistribution of pressure in the cavities leads to the movement of the piston in the power cylinder.

The nozzle apparatus of the gas distributor is made in such a way that at the middle position of the nozzle, its through hole is completely blocked by the receiver bridge, and the receiver openings are completely blocked by the walls of the nozzle. This design of the nozzle apparatus brings it closer to spool type distributors, providing a low gas flow rate in the neutral position of the nozzle and a large slope of the pressure characteristic of the distributor.



Rice. 43. Electromagnetic polarized device: *1* - working gap; *2* – permanent magnet; *3* - magnetic wire; *4* - control winding; *5* - anchor

In the gas distributor, an electromagnetic polarized rotary device is used to control the rotation of the nozzle (Fig. 43).
It consists of two U-shaped magnetic circuits, rectangular permanent magnets, an armature with which the nozzle is rigidly connected, and a control winding.

Permanent magnets create the main bias flux ÿ0, which closes along the magnetic circuits, passing through the working gaps and the end parts of the armature.

If the armature is in the middle position and the current in the control winding is zero (i.e., the flux ÿ created by the control winding is zero), then the magnetic field strength in the gaps along the north and south poles is the same. Due to the equality of the field strengths in both gaps, the electromagnetic forces acting on the armature are mutually compensated.

If we assume that under the action of an external moment the armature deviates from the middle position, then the cross-sectional areas of the gaps will change at a constant value of the magnetic flux of the permanent magnet. The equality of the field strengths under the north and south poles will be violated. As a result, the equality of the electromagnetic forces acting on the armature will also be violated and a moment will arise that tends to turn the armature in a direction with greater intensity (to restore the lost balance).

Thus, the armature of the gas distributor at equal currents in the control windings stably maintains the middle position, that is, the effect of the magnetic flux of permanent magnets on the armature is similar to the action of the centering spring. The value of the restoring moment of the “magnetic spring” is proportional, within certain limits, to the angle of deviation of the rotor from the neutral position.

When current passes through the control winding, a magnetic flux arises in the armature of the gas distributor, which passes through the armature and then branches into two fluxes ÿ/2, closing through the working gaps and magnetic circuits. The direction of the control magnetic flux depends on the direction of the current I, that is, the polarity of the control signal at the input of the force
calf.

The magnetic flux ÿ created by the control winding interacts with the field of permanent magnets ÿ0 - the fluxes are added or subtracted in the working gap depending on the sign of the current I. This leads to an inequality of field strengths in the working gaps and the appearance of a torque that tends to equalize the field strengths in both gaps. The anchor will deflect until the tensions are equal.

In the deflected position, the tensions are equal and no torque acts on the armature. Thus, the position of the armature of the gas distributor depends on the magnitude of the control current in the control winding of the relay.

In the gas distributor, the configuration of the poles of the magnets and the shape of the armature are selected in such a way that the angle of rotation of the armature relative to the neutral position is proportional to the magnitude of the current in the control winding. The direction of rotation of the armature corresponds to the sign of the current in the control winding.

Together with the anchor, the nozzle of the gas distributor also rotates. With a deflected armature, the overlaps of the receiving openings are also made unequal, as a result of which the gas jet flowing out of the nozzle creates a pressure difference in the cavities of the power cylinder RM.

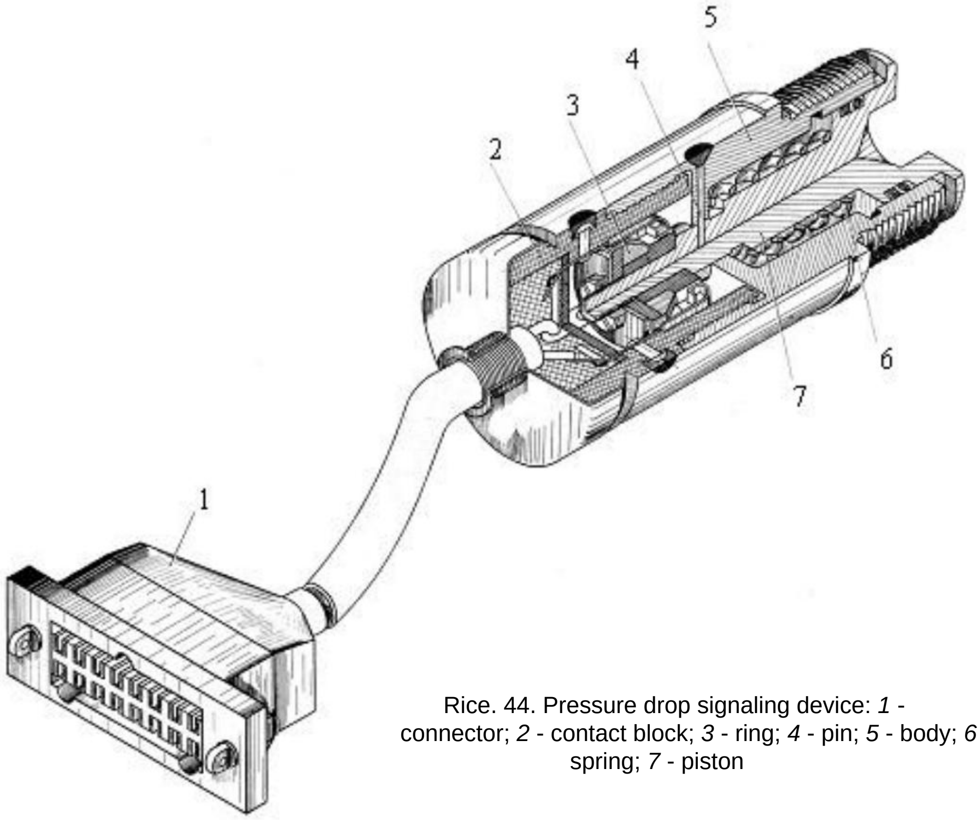
The design of the gas distributor is shown in fig. 42. Magnetic circuits *14* with permanent magnets *15* installed on them are glued on flange *6* and fixed on it with studs *16.* This assembly, together with armature *12* and coils *13 ,* is inserted into housing 3. The armature rotates in bearings *1.5.* Gas is supplied to nozzle *11* through bracket 7, flange *4* and nipple 2.

The nozzle is attached to the armature axis with screws 8. The outlet of the nozzle is a slot. The receiving part *10,* called the plug, is pressed into the bracket 9. By drilling in the bracket, the holes of the plugs are brought to the “A” plane, which is in contact with the plane of the power cylinder. The plug has two slot-like holes with a jumper between them. Sections
holes in the nozzle and the receiver are selected based on the given gas flow rate and the speed of the drive. The gap between the nozzle and the plug is selected using gaskets so that the limit
pressure in the gas generator of the drive did not exceed the maximum.

8.2. Pressure drop alarm

The pressure drop signaling device (Fig. 44) in the gas generator of the declination system is designed to issue the command “KPO” (“Switching the limitation of the rudder deflection angle”). On this command, the signaling device supplies a constant voltage of +27 V to the autopilot control unit to switch the mode of its operation in the final section of the trajectory, when the pressure in the combustion chamber drops to (0.1 ± 0.01) kPa. At the same time, the restriction of signals to the steering machines is organized at the level of 15º of the deflection of the rudders. The pressure drop signaling device consists of a steel case *5* with a contact block *2* fixed in it with

spring contacts, a steel piston *7* and a spring 6. A contactor with a contact ring 3 is fixed on the piston. The spring contacts of block *2* are connected to wires ending with a plug connector *1* to turn on the signaling device in the electrical system of the rocket.



Rice. 44. Pressure drop signaling device: *1* - connector; *2* - contact block; *3* - ring; *4* - pin; *5* - body; *6* - spring; *7* - piston

In the initial position, the signaling device contacts are open, since the piston is held in the middle position by pin 4 passing through the hole in the body and piston. At the moment of starting the gas generator of the declination system by gas pressure on the piston, pin *4* is cut off and the piston moves to the extreme left position. With a decrease in pressure, the piston moves to the right under the force of spring *6* and closes the spring contacts of block 2 with ring *3.* To ensure reliable operation, the contact block has two pairs

contacts.

Section 8 self-assessment questions

1. Explain the operation of the steering gear.
2. Explain the device of the gas distributor.
3. What elements does the gas-dynamic drive of the rudders consist of?
4. Purpose and device of the gas distributor of the gas-dynamic drive of the rudders.
5. Why is a feedback potentiometer used in a steering machine?
6. What determines the polarity and magnitude of the signal that controls the operation of the gas distribution caster?
7. What function does the electromagnetic polarized re where?
8. Explain the principle of operation of an electromagnetic polarized relay.
9. For what purpose, along with a pressure indicator in a rocket, is a recession indicator used? pressure?
10. How does the low pressure indicator work?

9. CHEMICAL CURRENT SOURCE

DC batteries are used as a chemical current source - a source of power for the onboard equipment of the rocket, which can be in one of the following states:

- in non-working, in which the current pulse on the filament of the electric igniter is not was supplied, the electrolyte is in a solid state;
- in the working one, in which the pyroheaters worked, the electrolyte is melted;
- in the unfolded.

Batteries are brought into working condition by supplying voltage of 20…35 V DC to the electric igniters from a ground power source for a duration of at least 0.01 s. Batteries brought into working condition provide the following constant voltages during the flight: +20 V; -20 V; ± 27 V; +25 V.

10. ELECTROMECHANICAL CONVERTER

The electromachine current converter is designed to supply alternating voltage to the onboard equipment of the rocket.

The converter is launched from a ground source of direct current with a power of at least 0.5 kW in the steady state and up to 2.0 kW in the starting mode, providing a voltage of 27 ... 31 V at the contacts of the missile's onboard connector. direct current.

The time for the converter to enter the mode is 1.5 s at idle when starting from ground source.

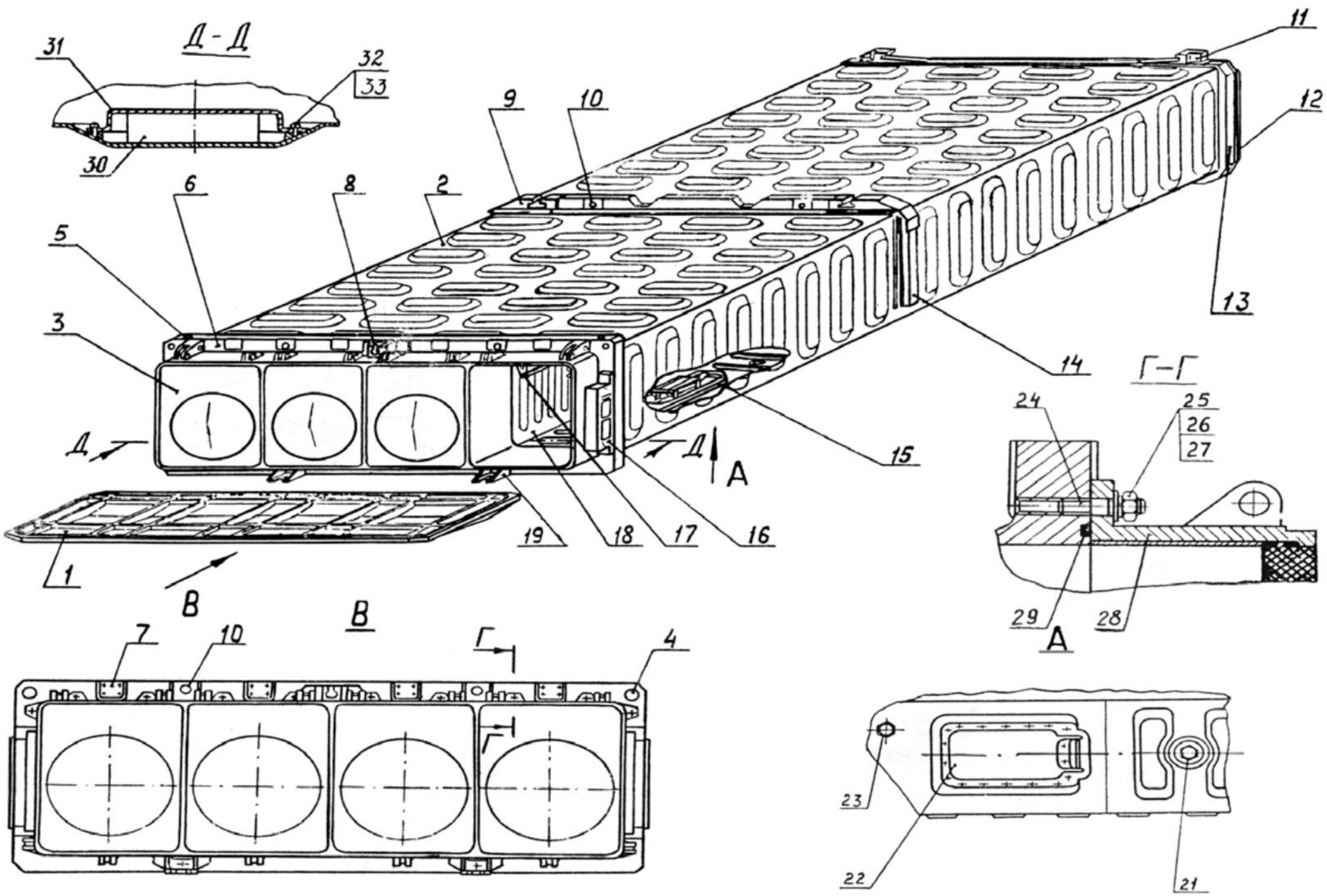
During operation, the converter outputs the following three-phase rockets to the on-board network nye alternating voltages: 36 V 1000 Hz; 5V 1000Hz.

11. TRANSPORT-LAUNCH CONTAINER

The transport and launch container (TPK) is designed for storage, transportation and launch of missiles (Fig. 45). It consists of body 2, divided by diaphragms *18* into four cavities intended for the installation of missiles, a one-time protective and sealing device *28* , and two covers: front *1* and rear *12.* Body *2* is an all-welded corrugated structure made of aluminum alloy and supported by three frames. On the front frame there is a bracket 8, which ensures the fixation of the TPK on the TZM when loading the combat vehicle, and a plate *7* for fixing the TPK on the BM. Fixation of the TPK from transverse movements during loading on the BM guides is provided by T-shaped grooves-yokes *9* on the middle and yokes *11* on the rear frames. The tightness of the housing is ensured by rubber gaskets on all butt joints.

On the front cover of the housing there are two holes closed with plugs. The holes are designed to check the tightness of the cavity under the front cover during the manufacture of TPK and to equalize the pressure in this cavity with the environment before removing the front cover.

Inside the cavities of the TPK, on the upper wall, guide beams *17* are attached to the frames with the help of bolts and steel brackets , on which the missiles are mounted. There are four hatches on the lower surface of the TPK body, which are closed with covers *22* with mechanisms for disconnecting electrical connectors *15,* which ensure the connection of the electrical circuits of the missiles with the launch automatics and the disconnection of the electrical connectors of the TPK from the onboard electrical connectors of the missiles during launch, and plugs *21,* providing access for switching the letter frequency.



Rice. 45. Transport and launch container: *1* - front cover; *2* - body; *3* - the cover is collapsing; *4* - hole; *5* - nest; *6* - front frame; *7* - plate; *8.19* - bracket; *9* - front yoke; *10* - lifting unit; *11* - rear yoke; *12* – back cover; *13* - rear frame; *14* – middle frame; *15* - mechanism for disconnecting the electrical connector; 16-electric connector; *17* - guide beam; *18* - diaphragm; *20, 23* - purge plug; *21* - plug hatch switching letter; *22* – cover of the electrical connector undocking mechanism; *24* - hairpin; *25* - nut; *26,27,33* - washer; *28* - ZGURD;
29 - gasket; *30* – desiccant (silica gel); *31* - cover; *32* - screw

To connect the TPK to the starting automation, there are onboard electrical connectors *16* located on the sides of the front frame of the TPK. To purge the internal cavities of the TPK with dry air during manufacture, in the back cover and on the lower surface of the TPK, at the front frame, there are purge holes closed by plugs *20* and *23.* The rocket is loaded into the TPK from the front end of the TPK. The rocket is fed into the TPK until

stop the earring of the ejection device into the grooves of the TPK guide. The rocket is fixed in the TPK in the axial direction by a removable jumper *1* (see Fig. 7). The transverse fixation of the rocket is carried out by yokes *9.11* (see Fig. 45), which are located in the grooves of the brackets on the middle and rear frames.

Questions for self-control in sections 9-11

1. What is a chemical current source? 2. What state can DC batteries be in at various stages of func positioning? 3. Appointment of the electric machine current converter. 4. What is included in the control channel drive circuit? 5. How is the rocket fixed in the TPK?

12. SEQUENCE OF OPERATION OF THE ROCKET AND ITS ELEMENTS

"Preparation" mode (duration of the mode can be 5…5.5 s): – steering gears are reset to zero; – voltage supply from the ground power source; – turning on the autopilot gyro motors; – operation of AP memory devices in the "tracking" mode; – memorization of information about the pitch and heading angles received in the ASA; – issuance of an address code to the radio equipment; – along the chain "Record"-logical "1"; - on the KRAZ circuit voltage +20 V; after 1 ... 1.5 s: - there is a forced heating of the magnetron filament; – issuance of an asynchronous launch pulse of the transponder is prohibited; – the counting and output circuits of the block are reset by the "Write" command; – in the initial state, the lower antennas are open and the upper ones are closed; - the address code is set, issued by three circuits from the starting automation equipment. **"Waiting"** mode (duration of the mode can be 5.5…60 s): – switching the power supply of BRU 36 to 1000 Hz from ground to onboard; – two free-running gyroscopes are powered from a ground source (in case of continued waiting for more than 5 s). **"Start" mode** (the command can pass starting from 6.5 to 6.1 s at any moment): – HIT output to nominal value; - switching the power supply of the BRU from ground to onboard; – for a time of 0.1…0.2 s along the "Record" circuit, the voltage is removed with a logical level "1"; – after 0.9 s, issuance of a command from the ACA to unlock free gyroscopes; – transfer of the storage device of the AM to the mode of storing information ("Memory" command) about the value of the declination commands at the end of the launch process;

– for a period of 1.5…2.0 s prohibition to overwrite the address code; - a command from the ASA to undermine the catapult squib.

Rocket launch: - separation of the onboard connector; – turning levers *30* and *33* (see Fig. 12);

– short circuit of push-button switches;
- launch of the steering gears;
– start of the HG declination system 0.31 s after turning lever *30* at the command of the time delay device of the command block; - the exit of the rocket from the TPK;

– disclosure of rudders;
- 0.25 s after the onboard connector is torn off - the time relay is triggered and the steering wheel is reset output machines;
– formation of control signals according to a given algorithm for the operation of rudders (declination path);

- vertical flight of a rocket up to a height of 10 ... 15 m.

Rocket flight:

- rocket declination (flight controlled by pitch and heading channels under the influence of aerodynamic and gas-dynamic forces on the aileron rudders);
– launch of the rocket engine 1 s after the lever *30* is turned at the command of the time delay device of the command block or 1 s after the lever actuation;
– operation of free gyroscopes (determination of current pitch and heading angles);
– CDR command from the BRU, switching the autopilot from the declination mode to the control mode (in 1.5… 2 s after the beginning of the declination);
– blocking of the control command, turning off the declination;
- connection of steering machines to the control path.

Control mode:

- removal of voltage +20 V in the KRAZ circuit;
– asynchronous mode of launch and operation of the transponder;
– radiation through the upper and lower antennas;
- determination of the position of the rocket by the SVR according to the angular coordinates according to the signals of the BRU;

first session:

– request pulse from the SPC;
– teams K1 and K2;
- generation of a CPR signal by radio equipment in the form of a DC voltage of +27 V;
- transfer of the autopilot to the mode of working out control commands (K1, K2);

current communication sessions:

– request pulse from the SPC;
- on command KZAZ, termination of the asynchronous mode of launching the transponder, switching to blue chronic support;
– pair switching of antennas;
– double confirmation of the largest signal in one of the receiving antennas;
– switching reception to the selected pair;
- transmission of signals of continuous and one-time commands to the rocket;
– to the gearbox autopilot – switching the autopilot operation modes (switching the autopilot gain factors, +27 V);
- into the radio fuse - KOS1-KOS4 in the form of a DC voltage corresponding to the level of logical “0”;

when approaching the target:

- KUV from the onboard radio equipment turns on the RV transmitter;
– HF radio command includes information processing unit (+27 V);
- the unit, taking into account the mode of operation of the RV, generates a response pulse;
– formation of delays by commands KOS1-KOS4;
- undermining the warhead.

In case of a miss (failure to receive a command from the RV or violation of the radio link for a time of 1.5 ... 2.0 s), the on-board radio control equipment issues the commands “Liquidation” and "Time", which close the circuit for the self-destruction of the rocket. The rocket self-destructs.

During the flight, as the SEC issues one-time commands, the onboard radio equipment controls leniya gives:

– to autopilot – “Switching the autopilot operation mode”;
- to the radio fuse - four commands "Relative approach speed" in the form of a DC voltage corresponding to the level of logical "0", as well as commands

“Radio fuze arming control” and “Radio fuze arming” as +27 V voltage.

In the event of a radio link failure for up to 100 ms or the absence of commands K1 and K2 in a row in three communication sessions, the “Control” signal is not removed, and the levels of commands K1 and K2 are remembered. If the radio link is broken for more than 100 ms, the “Control” signal is removed, and the commands are set to zero. When the radio link is restored, the “Control” signal is restored, and the command levels correspond to the levels transmitted by the transmission station to
mand

In case of violation of the radio link for a time of 1.5 ... 2.0 s, the on-board radio control equipment niya issues the “Time” command, which closes the circuit for self-destruction of the rocket.

Questions for self-control

1. What is the 9M334 anti-aircraft missile module?
2. List the composition of the complex.
3. What is placed on the base of the 9A331 combat vehicle?
4. Give a description of the detection radar.
5. Why the detection radar is a coherent-pulse radar.
6. Appointment of the television-optical visa.
7. For what purpose is the review of the space of the detection radar in the vertical planes?
8. How is the identification of the nationality of the target carried out? 9. Give a description of the guidance radar.
10. Phased antenna array (PAR), what is it?
11. Why is the guidance radar a coherent-pulse Doppler type radar?
12. List the functions performed by the guidance station.
13. What are the features of the operation of the complex and the mode of operation of the onboard equipment?
14. Why is the probability of detecting hovering helicopters higher than the probability of detecting gunships on the ground helicopters with rotating propellers?
15. What does the concept of “blind speed” mean in radar?
16. The main features of the anti-aircraft missile module 9M334.
17. Advantages and disadvantages of the aerodynamic design of the 9M331 rocket.
18. Explain the operation of the ejection device.
19. Give general information about the performance characteristics of the rocket.
20. What is the first rocket compartment?
21. What is placed in the second compartment of the rocket?
22. Appointment of sources of hot gas located in the second compartment of the rocket.
23. How does hot gas get into the rudder nozzle?
24. Explain the operation of the spring locking mechanism of the rudders.
25. What is located in the third compartment of the rocket?
26. List the composition of the equipment block.
27. How and when is the rocket letter frequency set?
28. The composition and purpose of the elements of solid propellant rocket motors.
29. How are the wings held in the folded position and how and when do they open?
30. What is the purpose of a wing block mounted on a bearing?
31. How is the rocket switched to onboard power?
32. The order of operation of the ejection device.
33. Name the sequence of functioning of rocket elements during ejection.
34. What happens to the rocket immediately after it leaves the TPK? 35. How is the 9M334 module equipped?
36. Typical stages of rocket flight.
37. How is the missile turned in azimuth in the direction of the target?
38. List the pre-flight modes of operation of onboard equipment.
39. What is done in the "Waiting" mode?
40. What operations are carried out in the "Preparation" mode?
41. What operations are carried out on the "Start" command?
42. When is the command to launch a rocket issued?

43. What operations with the rocket are carried out during the operation of the ejection device things"?

44. When is the command to reset the steering gears issued? 45. How is the control signal to the steering gears formed after the launch of the rocket? 46. How is the rudder unlocked? 47. How is the rocket controlled in the declination section? 48. When and how does a rocket engine start? 49. Why are the deflection angles of the rudders limited in the initial phase of the rocket flight? 50. When is the command to switch the rudder deflection limit switched? 51. How is the position of the rocket determined by angular coordinates? 52. When and how are the SPK commands transferred on board the rocket? 53. What commands are transmitted by radio control and radio vision equipment located

on rockets?

54. What is the essence of transmission of control command levels (K1, K2) by the phase-pulse method? 55. What determines the time interval "Tact"? 56. When is the ECU command issued? 57. When is the CT command issued? 58. Purpose of PIM. 59. How and when is self-destruction of a rocket carried out? 60. List the main sections of the rocket's flight path? 61. How are the rocket rudders oriented in flight? 62. How commands are generated to turn the rudders at roll angles63. What is the essence of the three-point guidance method? 64. What is the essence of the "half straightening" guidance method? 65. Advantages and disadvantages of the "three points" and "half straightening" methods? 66. Features of missile guidance when working on a low-flying target? 67. How is the possibility of the rocket hitting the earth's surface and false triggering of a radio fuse from signals reflected from it? 68. What is a kinematic link? $\varepsilon = 0$ and $\ddot{\varepsilon}$ 0 ? *69. What kind of feedback covers the rocket as an object of regulation? 70. What should the onboard radio control equipment do? 71. What functions does the onboard radio control equipment (BRU) perform? 72. What commands does the command transfer station (CTC) send? 73. What tasks does the onboard radio control equipment solve by executing the SPK commands? 74. List the main blocks of on-board equipment. 75. Why do BRUs use different power supply voltages? 76. What is the meaning of using levels logical "1" or logical "0"? 77. How does the BRU function in the "Preparation" mode along the "Record" chain? 78. What kind of BRU operates in the "Standby" mode? 79. What BRU functions in the "Start" mode? 80. What functions does the missile sighting station (SVR) perform?*

81. Purpose and operating modes of the transponder on-board radio equipment. 82. How is one of the two receiving antennas determined in flight in the BRU? 83. What does synchronous and asynchronous modes of operation of BRU elements mean? 84. When is the "Control" command issued? 85. What signals does the BRU give out during the flight? 86. How does the BRU work in case of a radio link failure? 87. When is a command issued to self-destruct a rocket? 88. Purpose of the command block. How are teams formed? 89. What functions does the autopilot perform? 90. What is included in the autopilot? 91. Why are there two linear acceleration sensors and three angular acceleration sensors in the autopilot?

ny and three free gyroscopes?

92. How is the loss of dynamic stability of the rocket prevented after leaving the TPK in the vertical leg of the flight? 93. What is the orientation of the aerodynamic planes (rudders and wings) of the rocket in flight? 94. How are control commands formed in the declination section?

95. How are control commands implemented in the declination section?
96. How is the restriction on the angle of rotation of the rudders on the initial part of the declination section removed? 97. Autopilot functions in control mode. 98. In what coordinate system are rocket control commands formed? 99. How is the roll stabilization of the rocket? 100. What is a dynamic trajectory? 101. What is a kinematic trajectory? 102. What is the essence of aiming a missile at a target? 103. What is a dynamic error? 104. Appointment of free gyroscopes. 105. The device of a free gyroscope. 106. Why is the maximum angle of rotation of the inner frame of the gyroscope limited? 107. Purpose of the angular acceleration sensor. 108. The principle of operation of the angular acceleration sensor. 109. Purpose and device of the linear acceleration sensor in the autopilot. 110. What functions are assigned to a radio fuse? 111. When and on what command does the radio fuse begin to irradiate the target? 112. How is the warhead demolition team formed? 113. List the constructive solutions that ensure that the target is covered by a stream of damage

elements in various conditions of the meeting of the missile with the target. 114. In what modes does the radio fuse work? 115. The order of operation of the radio fuse. 116. Components of a radio fuse and their purpose. 117. What are the main elements of the RV transmitter? 118. What is a magnetron for and how does it work? 119. Components of the radio fuse receiver and their purpose. 120. What functions does the information processing unit of the receiving device of the radio explosion perform?
vatel?
121. Where do the pulses come from to the counter of the information processing unit of the receiving device radio fuse?
122. How do you understand the phrase "coincidence in time of strobe and video pulses on a helmet where are the coincidences?
123. Why does a radio fuse have software sensitivity adjustment and a coarsening chain? 124. Due to what is the maximum efficiency of the warhead in the target area achieved? 125. What determines the area of operation of a radio fuse? 126. How is coordination of the operation area of the radio fuse with the expansion zone achieved?

splinters?

127. How is the increase in noise immunity of RV achieved? 128. What is the purpose of the safety-actuator (PIM)? 129. What functions does PIM perform? 130. When and on what command is the PIM included in the work? 131. List the conditions under which the protection stages are removed in the PIM. 132. How is the first stage of protection removed in PIM? 133. How is the second stage of protection removed in PIM? 134. How is the third stage of protection removed in PIM? 135. In what cases does PIM work? 136. Name the conditions necessary and sufficient to hit the target. 137. List the constructive solutions that ensure that the target is covered by a stream of damage

elements in various conditions of the meeting of the missile with the target.
138. How to build a kill zone for any target? 139. Describe the rocket engine. 140. Calculate the engine thrust in the starting and marching modes of operation. 141. List the main elements that make up a rocket engine. 142. How is the dual-mode engine ensured? 143. How and by what command is a dual-mode solid-propellant rocket engine launched?

144. How is the independence of the parameters of the engine from the pace environment?
145. Draw a curve of change in pressure in the engine chamber over time.
146. How is the engine sealed?
147. How is the bonding of the charge to the body?
148. How is the required stress-strain state of charge ensured?
149. What is a charge igniter?
150. How does a squib work and how does it work?
151. For what purpose, along with a pressure alarm in a rocket, is a spa alarm used? yes pressure?
152. How does the pressure alarm work?
153. Explain the operation of the steering drive.
154. Explain the device of the gas distributor.
155. What elements does the gas-dynamic drive of the rudders consist of?
156. Appointment and device of the gas distributor of the gas-dynamic drive of the rudders.
157. Why is a feedback potentiometer used in a steering machine?
158. What determines the polarity and magnitude of the signal that controls the operation of the gas distribution divisor?
159. What function does an electromagnetic polarized valve perform in a gas distributor? relay?
160. Explain the principle of operation of an electromagnetic polarized relay.
161. How is the pressure drop signaling device arranged?
162. What is a chemical current source?
163. In what state can DC batteries be at various stages of operation?

164. Appointment of an electric machine current converter.
165. What is included in the control channel drive circuit?
166. How is the rocket fixed in the TPK?

14. COMMENTS ON THE TEXT AND SOME QUESTIONS

1. To questions about the operation of the radar (questions 4 - 15)

The physical basis of radar is the scattering of radio waves by objects that differ in their electrical characteristics from the corresponding characteristics of the environment when they are irradiated. Moreover, the intensity of scattering or reflection of radio waves (RW) (the intensity of the secondary field) depends on the degree of difference between the electrical characteristics of the object and the medium, on the shape of the object, on the ratio of its dimensions and wavelength, and on the polarization of the RW.

The resulting secondary electromagnetic field consists of a reflection field propagating towards the irradiating primary field and a shadow field propagating behind the object (in the same direction as the primary field).

With the help of a receiving antenna and a receiving device, it is possible to receive part of the scattered signal, convert and amplify it for subsequent detection. Thus, the simplest radar can consist of a transmitter that generates and generates radio signals, a transmitting antenna that emits these radio signals, a receiving antenna that receives the reflected signals, a radio receiver that amplifies and converts the signals, and, finally, an output device that detects the reflected signals. As a rule, the amplitude (or power) of the received signal is small, and the signal itself is random. The low signal power is explained by the large

distance to the object (target) and the absorption of signal energy during its propagation on the one hand, and the size

goals on the other. The random nature of the signal is a consequence of the fluctuations of the reflected signal due to the random movement of the elements of the target of a complex shape during the reflection of the RW, chaotic changes in the signal amplitude during propagation, and a number of other factors. As a result, the received signal is similar to noise and interference in the receiving path in terms of the type, intensity and nature of the change.

Therefore, the first and main task of the radar is to detect a useful radio signal, i.e. making a decision about the presence of a useful signal in the mixture of a useful signal with noise coming to the input of the receiving path. This statistical problem is solved by a special device included in the radar device - a detector, in which an attempt is made to use the optimal (best) detection algorithm. The quality of the detection process is characterized by the probability of correct detection, when the signal present in the input implementation is detected, and by the probability of false alarm, when

interference occurs, but the signal itself is absent.

Most of the parameters of the received signal are a priori unknown, therefore, when detecting environment, you have to search for the desired parameter of the radio signal that distinguishes it from associated noise and interference.

*3. **Classification of radar stations [18]***

Radars are classified according to the following criteria:

– the origin of the radio signal received by the radar receiver (active radars (with active and passive response), semi-active and passive radars);

– the RV range used (radar of decameter, meter, decimeter, centimeter and millimeter ranges);

- the type of probing signal (radar with continuous (unmodulated or frequency modulated) and pulsed (incoherent, coherent-pulse with large and small duty cycles, with intra-pulse frequency or phase modulation) radiation);

– the number of used channels for emitting and receiving signals (single-channel and multi-nal with frequency or spatial division of channels);

– the number and type of measured coordinates (one-, two- and three-coordinate);

– method of measurement, display and removal of object coordinates;

- the place of installation of the radar (ground, ship, aircraft, satellite).

*4. **The principle of operation of the simplest radar station***

The number of simultaneously detected and tracked targets is determined by the speed of systems for obtaining and processing information about them. The device of a radar station is based on three components: a transmitter, an antenna and a receiver.

The transmitter (transmitter) is a high power electromagnetic signal source. It can be a powerful **pulse generator.** For centimeter-range pulsed radars - usually a **magnetron** or pulse generator. The transmitter operates, as a rule, in a pulsed mode, generating repetitive short powerful

electromagnetic impulses. Short

probing pulses are radiated into space through the **antenna .**

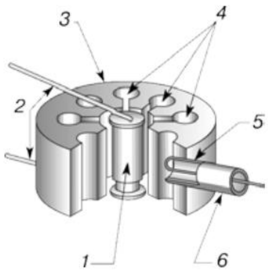
The antenna (radar) performs focusing of the transmitter signal and **beamforming,** as well as receiving the signal reflected from the target and transmitting this signal to the receiver. If transmission and reception are combined in one antenna, then these actions are performed **alternately,** and so that a strong signal leaking from the transmitting transmitter to the receiver does not blind the weak echo receiver, a special device is placed in front of the receiver, which closes the receiver input at the moment the probing signal is emitted.

The receiver (receiving device) provides reception, processing and selection of information tion from the received signal.

Thus, the radar serves to detect targets by illuminating them with an electromagnetic wave and then receiving reflections (echoes) of this wave from the target. Since the speed of electromagnetic waves is constant **(the speed of light),** it becomes possible to determine the distance to the target based on the measurement of various signal propagation parameters.

If there is an object (target) in the path of propagation of radio waves, part of the electromagnetic energy is reflected back towards the radar. The reflected signal through the antenna enters the receiver, is amplified, and enters the output device for indication and (or) processing (detector, meters).

*5. **Magnetron*** [19] is a multicavity device for generating microwave electromagnetic oscillations based on the interaction of electrons moving in a magnetic field along curvilinear trajectories with an excited electromagnetic field. Magnetron anode - massive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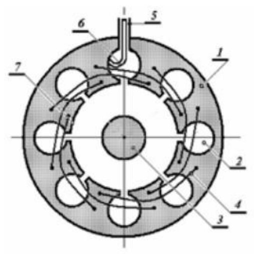
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Moving Target Selection Radar (MTS) can detect a target in clutter: it compares reflections from more than two or more pulse intervals. Any target that moves relative to the radar produces a change in the signal parameter (stage in serial SDM), while the clutter remains unchanged. Interference is eliminated by subtracting reflections from two successive intervals. In practice, noise removal can be done by algorithms in software.

An unavoidable disadvantage of MDCs operating at a constant PRF is the inability to detect targets with specific circular velocities (targets that produce phase changes of exactly 360°). The rate at which a target becomes invisible to the radar depends on the operating frequency of the station and on the PRF. To eliminate the disadvantage, modern SDCs emit several pulses with different PRFs. PRF are selected in such a way that the number of "blind" speeds is minimal.

Pulse-Doppler radars, in contrast to TDC radars, use a different, more complex method of getting rid of interference. The received signal, containing information about targets and interference, is transmitted to the input of the Doppler filter unit. Each filter passes a signal of a certain frequency. At the output of the filters, the derivatives of the signals are calculated. The method helps to find targets at given speeds, can be implemented in hardware or software, does not allow (without modifications) to determine the distance to the targets. To determine distances to targets, you can divide the pulse repetition interval into segments (called range segments) and apply a signal to the input of the Doppler filter block during this range segment. It is possible to calculate the distance only with multiple repetitions of pulses at different frequencies (the target appears at different distance segments at different PRF).

An important property of pulse-Doppler radars is **signal coherence** - phase dependence Simplicity of sent and received (reflected) signals.

Pulse-Doppler radars, in contrast to radars with SDC, more often detect low-flying common goals.

8. ***Coherence*** - a coordinated flow in time and space of several oscillatory or wave processes, which manifests itself when they are added. Oscillations are called coherent if the difference between their phases remains constant (or regularly changes) in time and, when the oscillations are added, determines the amplitude of the total oscillation.

9. ***Intrapulse modulation (frequency or phase). Modulation*** is the physical process of controlling carrier oscillations. Types of modulation (amplitude, frequency, phase) are characterized by: – depth of amplitude modulation – maximum relative amplitude deviation

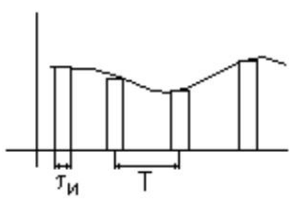
there from the middle;

- frequency deviation **-** the maximum frequency deviation both at frequency and at phase modulation;

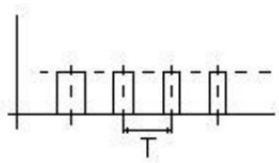
– index of angular modulation – maximum phase change.

For undistorted transmission of a message, it is necessary that the width of the message spectrum be small compared to the carrier, and for this it is necessary that the relative change in the modulating function be small over one period of the carrier oscillation. In pulse modulation, a sequence of rectangular pulses is used as a carrier of control signals. With radio signals, this sequence is applied to a high-frequency oscillation (double modulation).

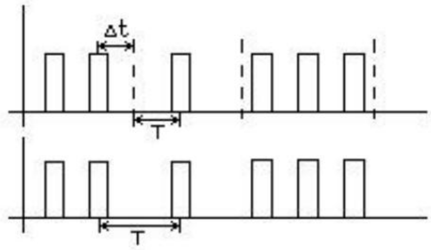
Pulse amplitude modulation (AIM), when, according to the law, I control signal changes increment pulse amplitude.

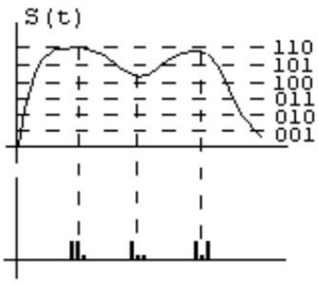


Pulse duration modulation (DIM), when the pulse duration changes according to the law of the control signal. Sometimes this kind of modulation is called *shi modulation. rotary pulse (PWM).*



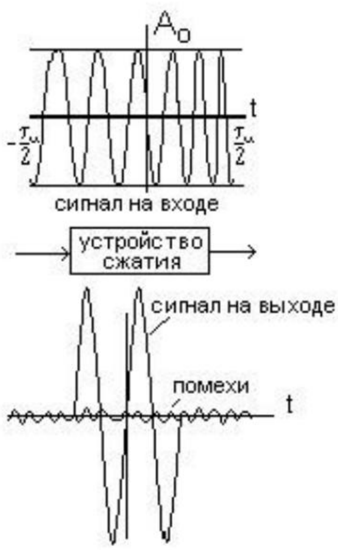
Time pulse modulation 3) *(TIM),* when, according to the law of the control signal, the pulses are shifted along the time axis (it can be phase (PIM) or frequency (PFM)).





Pulse code modulation (digital).
Each signal level (quantized) is assigned a specific number (code), usually in the binary system. Instead of transmitting the signal value *s(t)* , at the instants of counting the function *s(t)* , a number is transmitted (in the form of a combination of narrow pulses) corresponding to the number of the signal level at the given momen

Signals with intra-pulse frequency modulation are widely used in radar. The most commonly used linear increase in frequency from the beginning to its end.



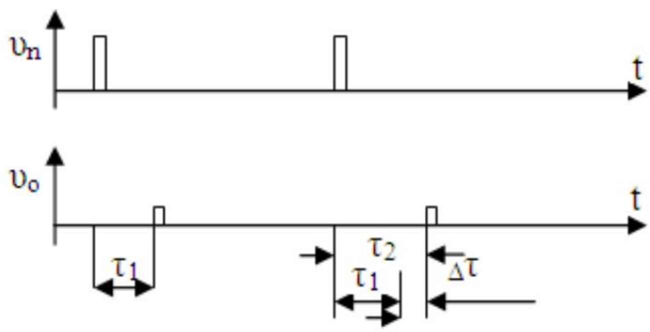
The practical significance of chirp-modulated (chirp) signals lies in the possibility of significant signal compression upon reception with an increase in its amplitude above the noise level.

This is achieved by a delay device with a delay time that decreases with increasing signal frequency. In this case, the output will be the addition of low frequency oscillations related to the beginning of the pulse and higher frequency oscillations observed at its end.

10. ***To question 15. Blind speed*** **is** the radial speed of movement of an object of radar observation, at which the Doppler frequency shift of the signal reflected from the object is equal to or a multiple of the frequency of repetition of pulses emitted by the radar, which excludes the possibility of measuring the speed of the object by the radar station. Radars, as a rule, work on the principle of receiving a reflected wave.

Active radars in the passive mode of operation record all objects that reflect waves: thunderclouds and clusters of birds. But it also allows you to better know the air situation. The accuracy of radars in range is not worse than 150 m. The measure of time in the radar is 1 ÿs. For 1 ÿs, the radar beam travels 300 m. $S = c\ t = (3\ 10^{8})\ (10^{-6}) = 3\ 10^{2} = 300$ m. The range is determined from the delay time of the reflected signal (Fig. 47):

$$D = c\ t_{zap} / 2 = (3\ 10^{8})\ 10^{-6} / 2 = 150 \text{ m}$$

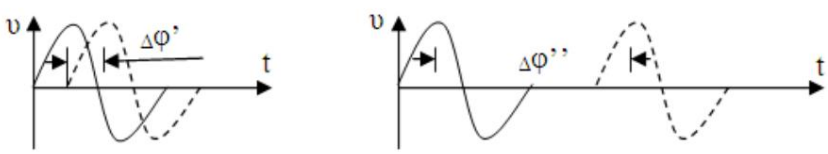


Rice. 47. Delay time of the reflected signal

Based on the accumulation of temporal changes in the reflected signal on the radar screen, the operator determines the change in the distance of the target from the radar station antenna. A similar effect underlies the Doppler principle, which is used in the mode of operation of the radar - SDC (SPC), that is, the selection of moving targets (selection of moving targets). This mode is used to distinguish targets against the background of passive interference. However, it also has disadvantages. The range of the radar in the SDC is 60 ... 75% of the liability. A significant disadvantage of the SDC is the manifestation **of "blind speeds".** These are the flight speeds at which the aircraft (LA) moves in space during the sending. The phase shift of the Doppler frequency will be constant when the aircraft moves during the time between pulses equal to the passage of a half wave and a multiple of *K* (Fig. 48).

$$S = ÿ \cdot ÿ / 2,$$

where *K* = 1.2 ... will determine the first, second ... fifth "blind speeds".



Rice. 48. Doppler phase shift

In the general case, the value of "blind speeds" can be determined from the following relation Wsl = 0.018 *K* ÿ *Fn* where 0.018 is a constant coefficient, *Fn* is the number of pulses per second.

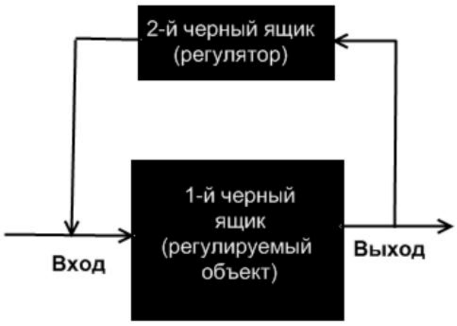
Synchronization of the movement of the electron beam sweep on the radar screen with the rotation of the antenna is achieved by the coincidence of the mechanical and electrical parts through the antenna synchro-sensors and the synchro-receivers of the signal amplifier of the converting equipment. The accuracy of the mechanical part of the best radars, both domestic and foreign, reaches 0.1º, and the resolution over the width of the antenna radiation pattern is 0.5º.

11. ***To question 27. Letter frequency* -** the frequency of the receiver and transmitter, set keyed on the rocket in order to increase the noise immunity of communication lines.

12. ***To question 29. Torsion*** - a spring in the form of a torsion shaft.

13. ***To question 69. Feedback. Positive and negative feedback.*** Any system can be represented as a black box. The concept **of feedback** (Fig. 49) assumes that a change in the output signal of one black box is transmitted through some transfer function of the second black box to the input of the first. As one of the implementation options, the entire output signal of the first black box is fed (added, subtracted, multiplied, divided, etc.) to its own input. The whole signal is also just a signal change in relation to the zero output level.

By **negative feedback is** meant such feedback, in which a change in the output signal is transmitted to the input of the black box in such a way as to suppress (compensate) this change. That is, negative feedback "holds" the output parameter unchanged. Very important feedback parameters, even with the right choice of transfer function, are



Rice. 49. The concept of feedback

sia:

is the response rate to a change in the output signal (time delay). If this parameter is chosen incorrectly, then either the system enters the self-oscillation mode (reaction time too short), or the control does not keep up with the process (reaction time too long);

is the sensitivity of the system to a change in the output signal. If this parameter is chosen incorrectly, then either the system enters the self-oscillation mode (too high sensitivity), or the regulation does not keep up with the process (too low sensitivity);

– the provided possibility of changing the parameters of the transfer function for tasks, which also require external regulation of the output signal level (output control).

By **positive feedback** (PFC) is meant such feedback, in which a change in the output signal is transmitted to the input of the black box in such a way as to amplify (increase) this change. That is, positive feedback "accelerates" the change in the output parameter. Among the practical general engineering applications of POS, it is worth highlighting the use of an output signal with a time delay to excite the system. A huge number of electrical solutions (amplifiers, self-oscillating systems, signal generators) are based precisely on the POS phenomenon.

14. ***To question 83. Asynchronous and synchronous modes of operation of the BRU elements.***

When exchanging data between network nodes, three methods of data transfer are used:

– simplex (unidirectional) transmission (television, radio);

- half-duplex (reception and transmission of information are carried out alternately);

– duplex (bidirectional), each station simultaneously transmits and receives data

nye.

Serial transmission is most often used for data transmission in networks. The following serial transmission methods are widely used: asynchronous and synchronous

naya.

With asynchronous transmission, each character is transmitted in a separate package (Fig. 50). The start bits alert the receiver to the start of a transmission. Then a character is transmitted. The parity bit is used to determine the validity of the transmission (parity bit = 1 if the number of ones in the symbol is odd, and 0 otherwise). The last bit - "stopbit" signals the end of the transfer.

The advantages are a simple well-established system, inexpensive (compared to synchronous) interface equipment.

Disadvantages of asynchronous transmission: a third of the bandwidth is lost in the transmission of service bits (start/stop and parity); low transmission speed compared to synchronous; with a multiple error, it is impossible to determine the reliability of the received information using the parity bit.

Asynchronous transfer is used in systems where communication occurs intermittently and does not require a high data rate. Some systems use the parity bit as a character bit, and information control is performed at the level of communication protocols.

Rice. 50. Asynchronous data transfer

When using the synchronous method, data is transmitted in blocks (Fig. 51). To synchronize the operation of the receiver and transmitter, synchronization bits are transmitted at the beginning of the block. Then the data, the error detection code, and the end of transmission character are transmitted. In synchronous transmission, data can be transmitted both as characters and as a stream of bits. The error detection code is usually a cyclic redundant error detection code (CRC). It is calculated from the content of the data field and allows you to unambiguously determine the reliability of the received information.

Advantages of the synchronous method of information transfer: high efficiency of data transfer; high data transfer rates; robust built-in error detection mechanism.

Disadvantages - interface equipment is more complex and therefore more expensive.

Rice. 51. Synchronous data transmission

14. To question 90. On the composition of the autopilot

Two linear acceleration sensors are used to measure linear accelerations and generate a signal in the form of a DC voltage, the magnitude of which is proportional to the linear acceleration acting in the direction of the measuring axis.

Three angular acceleration sensors are used to measure the angular accelerations of the rocket relative to a tightly coupled coordinate system.

Three free gyroscopes serve to determine three angles (course - ÿ , pitch - ÿ and roll - ÿ) relative to the starting coordinate system.

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