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The Expedition on Mercury

Dr. Alexander Rubinraut

Abstract **—A project of an expedition on the planet Mercury is contemplated. The expedition begins from a preliminary flight of the space train, which purpose is to deliver onto the Mercury orbit a tank-container with working substance, which is used during the return flight onto the Earth orbit. Onto the Mercury orbit a space refueller is also delivered, which is intended for refuelling on the surface of Mercury of the hydrogen-oxygen rocket engine of the takeoff –landing capsule. The main flight is carried out by a space train consisting of a locomotive, a tank-container and the takeoff-landing capsule. After landing on the surface of Mercury three astronauts perform a complex of astronomical, physical and geological studies of Mercury. While using a developed vehicle-merkuromobil, the expedition crew commits two exploratory trips along the surface of Mercury. The duration of the expedition - 56 days, the cost - 2 billion. $.**

Keywords—**Mercury, space train, space refueller, merkuromobil, cryogenic motorized wheel, orbital space laboratory.**

At the beginning of the 20 century a new science - astronautics was born. And at the end of the century man has mastered the near-Earth space and has visited the Moon. The twenty first century probably will be the century of mastering of interplanetary space of the solar system. Flights and expeditions towards all planets - satellites of the Sun will begin. As the calculations show, even the current status of space technology allows it to implement .

In this connection, Mercury, the closest to the Sun, the smallest and the "fastest " planet of solar system is of particular interest.

Astronomical study of Mercury has started relatively recently, although the first observations by means of a telescope were conducted still by Galileo Galilei. In year 1929 Eugenius Antoniadi has published the first map of the Mercury surface. The first detailed studies of the planet were implemented in 1975 year with the help of the spacecraft Mariner 10, which has approached to Mercury for a distance of 300 km.

The spacecraft “Messenger”, launched by NASA in August 2004, has carried a flyby of Mercury (in January 2008) and in March 2011 has entered into its orbit.

Some remarkable discoveries were made, including the fact that Mercury has phenomenal structure of the magnetic field, which is asymmetrically relative to poles and has whirlwinds of magnetic flux. Thanks to this research it became clear what can be expected by the astronauts, which are going to visit Mercury. It was found that the Mercury has practically no atmosphere . During the day, which the duration is equal to 59 earthdays, the surface temperature reaches 340°C . At night the Mercury surface is cooled to -170°C.

The Mercury's surface resembles the surface of Moon. But on the Mercury surface there are the rock formations (scarps) with toothed slopes stretching hundreds of kilometer. For example, the ledge "Discovery" has a length of 350 km with an altitude of 3 km. (On the Moon there are no such formations).

It should be reminded that the planet Mercury moves around the Sun at a speed of 48 km/s along elliptic orbit, approaching the Sun at a distance 0.3 A.U. and moving away to a distance of 0.46 A.U. One revolution around the Sun takes 88 earthdays. The inclination of Mercury's orbit to the ecliptic plane is only 7 degrees. Here's why, there are no seasons on Mercury, as on Earth, and there are areas near its poles, where the Sun's rays do not penetrate. The measurements conducted by the spacecraft "Mariner 10” have showed that Mercury is surrounded by magnetic field, whose intensity on the surface is $2 \cdot 10^{-2}$ G, i.e.100 times lower than on the surface of the Earth. As a result of the interaction of the solar wind with the magnetic field,

such a magnetosphere of the planet has formed, which has a complicated picture of the charged particles distribution. The study of the magnetosphere of Mercury is waiting for its continuation. The conducted researches have proved, that the conditions of the astronauts' stay on the surface of Mercury are similar to the stay on the Moon or Mars. Free fall acceleration on the Mercury surface is almost the same as on Mars, and is 3.8 m/s ².

Thus, perhaps the time has come to undertake an expedition towards Mercury. This assertion is based on the works on the development of technical devices for flights towards planets of the solar system, performed by the author in 2006-2016.

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In the year 2006 the electrorocket magneto plasma engine with superconducting field coil, in which the current is directed along the axis of the engine, was invented. This allows to increase the efficiency of electrorocket engine by 2 times [1].

In year 2010 the design of a space train with the locomotive, which contains a power plant with gas nuclear reactor, a MHD generator and a turbogenerator for power supply of electrorocket engines, was developed. In the train there are also tanks-containers with working substance and the takeoff-landing capsule with cabin of astronauts. Each element of the space train is launched using carrier rocket Ariane-5 on the Earth orbit, where the coupling of the train takes place by means of docking [2]. In year 2013, a project of an expedition on Mars was developed, which for reducing of the flight duration provides for preliminary delivery into the orbit an tank-container with working substance. The working substance is used for flight of the train from Mars orbit to the Earth orbit [3]. It should be reminded, that if to fly from Earth orbit in the direction off the Sun, at a distance of 0.52 AU there is orbit of Mars , and if you fly towards the Sun, at a distance of 0.61 AU is the orbit of Mercury.

That's why after implementation of the expedition on Mars, an expedition on Mercury can well become a reality.

The purposes of the expedition:

- Observations over the Sun during the orbital flight towards Mercury.
- Landing of the inhabitable capsule on the surface of the Mercury and the going out the crew of the expedition onto the surface.
- The researches of the Mercury surface by means of moving in polar and middle latitudes.
- Analysis of soil and collection of samples.
- Study on the magnetic field and magnetosphere.
- The launching of an orbiting space lab into orbit
- around Mercury.

I. The Concept Of High-Speed Flight On Mercury.

The concept was based on the methodology of carrying out the expedition, which is analogous to the methodology of the successfully performed expedition on Mars [3].

In accordance with this methodology, the expedition on Mercury begins with preliminary flight of space train, which purpose to deliver into Mercury orbit the tank-container with working substance, which later is used for the return flight of the expedition from Mercury orbit onto Earth orbit.

Scheme of the space train for the preliminary flight towards Mercury is shown in Fig.1

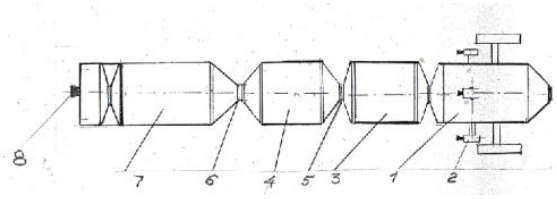

Fig. 1

The space train is formed on the Earth orbit. It is put in motion by a locomotive 1, which has 4 electrorocket engines with thrust of 250 N each. In the internal cavity of the locomotive 1 is placed on-board power plant with a total capacity of 10000 kW.

The detailed description of the design of the locomotive and the onboard power plant is given in [3]. It is assumed that the locomotive 1 is constantly used for flights from Earth orbit into the orbit of Mars. At the beginning of the preliminary flight on Mercury the lokomotiv 1 is in circumterrestrial orbit . The tank-containers 3 and 4 are put also into this orbit when forming of the train (Fig. 1). In these tanks-containers there is the working substance - hydrogen in liquid state , which provides electro reactive movement of the train.

Tank-container 3 is used for flight from Earth orbit into orbit of Mercury and for the return flight of the locomotive 1 from orbit of Mercury onto Earth orbit.

Tank-container 4 remains on orbit of Mercury up to the arrival of the expedition during the main flight.

The last "car" 7 of the space train (Fig. 1), which was connected, when using the docking unit 6, is needed for delivering on the surface of Mercury a mobile device-"merkuromobil". In addition, the car 7 is a refueller of fuel and oxidizer for chemical rocket engine of the takeoff-landing capsule, in which the crew of the expedition is located during main flight on Mercury. The descriptions of the designs of the refueller 7 and the "merkuromobil " are given below.

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Application of the refueller is a special feature of the flight on Mercury.

It is due to the fact, that there is no atmosphere on Mercury. Therefore, when landing on the surface of Mercury, it is impossible to use a parachute, as it happens when landing a spacecraft on the surface of Mars and therefore the braking of takeoff-landing capsule can be carried out only with the help of a chemical rocket engine operating in braking mode.

When braking of the takeoff-landing capsule on the Mercury orbit and when landing on the surface of Mercury, 60% of fuel and oxidant, which are in cryogenic tanks, are consumed.

Therefore in order to provide the take-off of the capsule from the Mercury surface and its entering into the Mercuury orbit one needs to fill the tanks with liquid hydrogen and liquid oxygen.

When forming of the train (Fig.1), the refueller is put into circumterrestrial orbit. Being in the circumterrestrial orbit, the refueller 7 with the help of chemical rocket engine 8 approaches the space train.

After the docking (when using the docking unit 6, which is located in the butt end of the tank- container 4) the space train is ready for preliminary flight towards the Mercury orbit.

The flight trajectory from Earth orbit into the orbit of Mercury was developed using the astrodynamic program, which tracks the interaction of the space train with the Sun and the planets Mercury, Venus and Earth in course of their continuous orbital movements[4].

After entering of the space train (Fig. 1) into the Mercury orbit its separation takes place. With the help of docking assemble 5 the locomotive 1 together with the tank-container is disconnected from the tank-container 4. The electrorocket engines 2 of the locomotive are switched on. When increasing of the speed from 3.1 km/s to 4.3 km/s the space train which is shown in Fig. 2, begins the return flight from Mercury orbit towards the orbit of Earth.

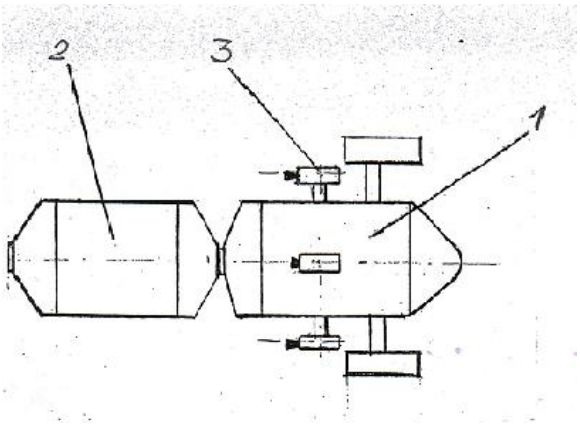

Fig. .2

During the return flight, the working substance, which was left over in tank-container 2 (40% of its volume) (Fig. 2), is used .

The cars 4 and 7, which are remained in Mercury orbit, are separated using the docking assemble 6 (Fig. 1). The tank-container 4 remains in Mercury orbit, waiting for arrival of the expedition. The refueller 7 with the help of chemical rocket engine 8 moves away from the tank-container 4, while remaining on the Mercury orbit. The landing is carried out in automatic mode using a program, which is introduced in computer control system.

The chemical rocket engine 8 (Fig.1) is switched on. The refueller 7 makes a manoeuvre with braking and when decreasing of the speed up to 3 km/s it loses weightlessness.

Using chemical rocket engine 8, the refueller 7 hovers above the surface of the planet Mercury at height of 30 km. Next, with the help of the rocket engine 8, the soft landing of the refueller on the Mercury surface is carried out. In this project as the place for landing of expedition on the Mercury surface , a vast space of the flat surface in the crater "Shakespeare" is being defined.

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Exactly in this place with coordinates 150º of North latitude and 50º of East longitude , the landing of the refueller is carried out. The refueller will start to operate after arrival of the crew of the expedition .

The space train now consisting of the locomotive 1 and the tank-container 2 (Fig. 2) returns onto the orbit the Earth.

The next stage of the expedition - the realization of the main flight on Mercury. For this purpose, in orbit of the Earth the space train, shown in Fig. 3 , is formed.

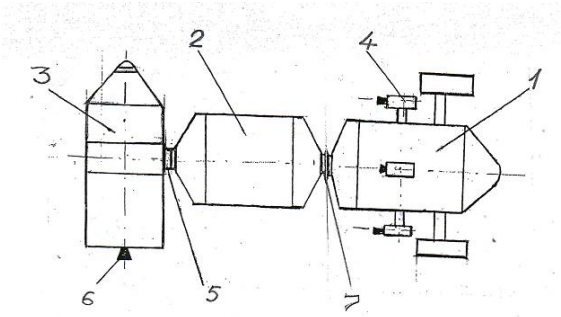

Fig. 3

The locomotive, which has come after the preliminary flight, is connected with the tank-container 2 with the help of the docking assemble 7. The tank-container 2 performs two functions. The first one: as a storage of the working substance for electrorocket engines 4 of the locomotive. Its second function is that after emptying it turns into a Mercury satellite , in which the necessary equipment with power supplies can be installed.

This circumstance gives the possibility to turn the tank-container 2 in a research laboratory that operates in automatic mode and performs the permanent monitoring of the Sun activity directly from the orbit of Mercury.

The formation of the space train (Fig. 3) is finished by connecting of takeoff- landing capsule 3. As the takeoff-landing capsule, the Martian takeoff-landing capsule [3] is used, which to the scheduled time of the flight on Mercury came back from a regular flight to Mars.

While being by a moorage of the international space station ISS, 3 the capsule 3 has passed the routine maintenance . The cryogenic tanks with liquid hydrogen and liquid oxygen, which are necessary for operation of the chemical rocket engine 6 and are located inside of the capsule, are filled.

Everything, what is needed for conducting the expedition, has been loaded into containers of the capsule 3. The crew of the expedition, consisting of 3 astronauts, passes through the gateway from the orbital station aboard the capsule 3.

The chemical rocket engine 6 is switched on and the capsule 3 approaches the space train, which is moving along the circumterrestrial orbit. After approaching and moorage the capsule 3 docks the tank-container 2 using the docking assemble 5.

The astronauts switch on an artificial gravity system and capsule 3 starts to rotate relative to the longitudinal axis in the cryogenic bearing, located at the butt end of the tank-container 2.

Next, the electrorocket engines of the locomotive 4 are switched on, the space train is accelerated and leaves the Earth orbit. In order to calculate the trajectory of the interorbital flight , the picture of gravitational field of solar system within the zone of influence of three planet, which are closest to the Sun, is determined (with the help of an astrodynamical program). The space train is the body of variable mass, which is under the influence of this field [4].

The flight trajectory which is obtained as a result of this calculation is shown in Fig. 4 and the process of the changing the speed and the weight of the train during the movement is shown in Fig. 5.

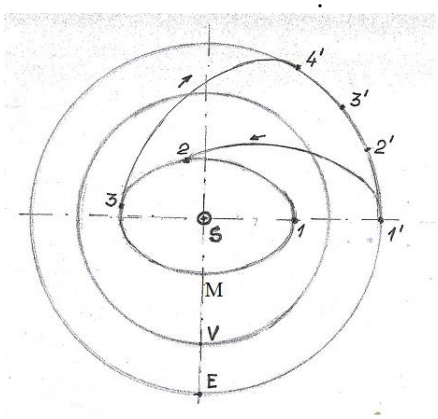

Fig.4

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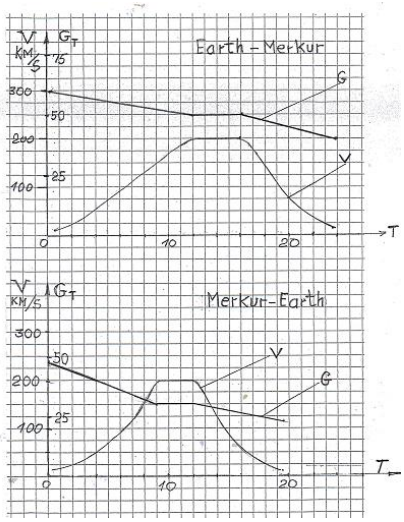

Fig. 5

As it can be seen from Fig. 4, the start of the space train is planned to carry out at a moment of the least opposition between the orbit of Mercury (point 1) and the orbit of Earth (point 1'). And as it can be seen from Fig. 5, the acceleration of the space train up to speed of 200 km/s occurs within 12 days. Next, the cruise electrorocket engines 4 of the locomotive (Fig. 3) are turned off and the train during four days moves by inertia.

According to the program of the expedition during the flight the astronauts carry out scientific monitoring of the Sun condition. It should be recalled that man was never so close to the Sun. The distance to the Sun is 50 million km. (one third the distance to the Earth).

The electrorocket engines of the locomotive are switched on, while changing the direction of their traction force on 180º. Owing to working substance consumption, the weight of the train is now 50 t. The speed decrease of the train from 200 km/s up to the orbital velocity on Mercury (3,1 km/c) occurs within 8 days.

The space train approaches the orbit of Mercury and its gravitational influence increases.

The moment of entering of the space train into Mercury orbit comes. Mercury in this moment is at the point 2, and Earth is at the point 2 ' of its orbit around the Sun (Fig. 4).

While moving along orbit around Mercury, the space train is located at an altitude of 30 km. from its surface.

The astronauts perform monitoring of the Mercury surface. Next the command for splitting of the space train is given. The separation of the space train is carried out with the help of docking assembles 5 and 7. The takeoff-landing capsule 3 with the help of a chemical rocket engine 6 moves away from tank-container. It should be reminded, that at time of the arrival of the expedition there is already one artificial space body on orbit around Mercury.

It's the tank-container filled with liquid hydrogen, delivered during the preliminary flight (see position 4 in Fig.1). The space locomotive 1, using the electrorocket engine 4, moves on approaching with the tank-container. After the approaching the locomotive docks with the full tank-container, using a docking assemble 7.

The empty tank-container continues to move along circular orbit around Mercury.

According to the project of the expedition this artificial satellite of Mercury should now perform the function of a space research laboratory.

For this purpose a new design of the tank-container has been developed, which equipped with automatic control system and devices for the permanent monitoring of the Mercury surface as well as the processes, which take place on the Sun.

The takeoff-landing capsule (Fig. 3) remains on a circular orbit around Mercury.

And now the most crucial moment of the expedition comes. The astronaut, who performs duties of navigator, puts the takeoff-landing capsule on the original position for landing at a given point on the surface of Mercury.

The chemical rocket engine is switched on, the capsule decreases its speed and when the speed achieves 3 km/sec the capsule loses weightlessness.

Using chemical rocket engine 6 the capsule smoothly moves towards the surface of Mercury and at the same time occurs its horizontal movement.

The pilot and the navigator of the expedition lead out the capsule to the point of landing on the surface in the valley "Shakespeare" at a distance of 20 meters from the refueller, which stands there. The modern capabilities of landing are quite in a position to do so.

Of course, astronauts must practice the realization of this operation on the surface of the Earth. After landing on the surface of the Mercury the astronauts emerge from the landing capsule and are going towards the refueller.

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Next, they bring the refueller back into service and using the corresponding cables provide power supply for all the systems of the refueller. The location of the refueller 1 and the takeoff-landing capsule 3 on the surface of Mercury is shown in Fig. 6.

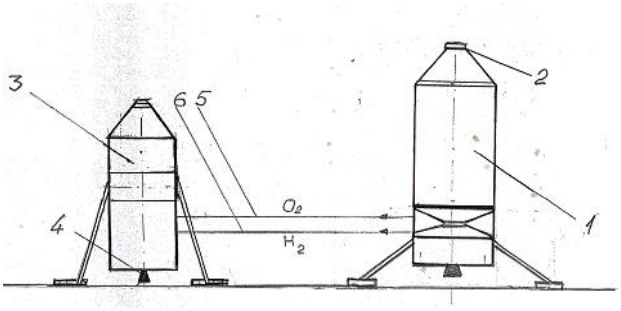

Fig. 6

Astronauts master movement in spacesuits on the surface of Mercury. Next, they with the help of flexible cryogenic hoses 5 and 6 interconnect the cryogenic tanks with liquid components, which are located in the capsule 3 and in the refueller.

The cryogenic pumps are switched on and liquid hydrogen needed as fuel for chemical rocket engine 4 is pumped via pipelines 6. The liquid oxygen needed as the oxidizer is pumped via pipelines 5.

After refilling of the tanks the takeoff-landing capsule 3 is ready for take-off from the surface of Mercury at any time.

Astronauts open hatch of the refueller 1 and using an elevator unload a vehicle -“merkuromobil”. The descriptions of designs of the refueller and the merkuromobil are given below. The merkuromobil is driven by electric motors, which are powered by fuel cells, operating on hydrogen and oxygen. Using cryogenic pipelines 5 and 6, astronauts fills the tanks of the merkuromobil with fuel and oxidizer from refueller 1. After testing the movement on the surface of Mercury, two astronauts take places in the cabin of the merkuromobil. The third member of the crew remains on the base of the expedition inside the takeoff-landing capsule 3.

According to the program of the expedition crew commits two research trips across the surface of Mercury

The route of the first trip: beginning from the valley "Shakespeare" in the direction of the North Pole. Expedition moves across the surface along the designated route with an average speed of 40 km/h and overcomes 600 km per day.

In two days of merkuromobil reaches 83° of north latitude. The choice of the north direction , as priority, is due to the fact that the radar studies of the circumpolar regions of Mercury has revealed that there are areas of depolarization of 150 km size.

The scientists assume that it is the ordinary water ice. Astronauts are exploring the polar craters of Mercury. After the completion of the travel along the polar route the merkuromobil returns to the base.

During three days the astronauts work on the program, which includes study of the soil using drilling installation. For delivery to Earth astronaut- geologist collects a special collection.

In addition, a study of the negligible atmosphere of Mercury is carried out. Astronaut-astronomer examines the starry sky of Mercury and measures the amount of solar wind. Special attention is given to study of a magnetic field. In the area of the capsule location the devices for continuous measurements of the magnetic field are being installed.

The second trip across the surface of Mercury begins. In the project the second route of the expedition was developed , which can be traced on a map of Mercury, shown in Fig. 7.

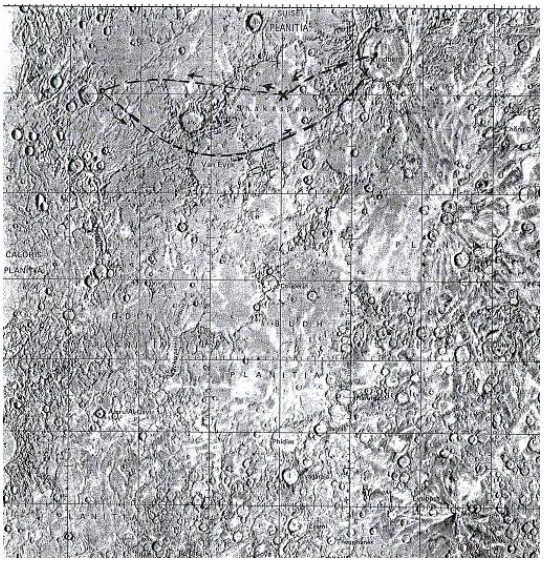

Fig.7

From the valley "Shakespeare" the merkuromobil shifts in the spacious plateau “Van Eyck” and reaches the mountain range “Zeehaen Rupes”.

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Astronauts carry out geological studies of the toothed escarp . Next, the crew examines and explores the deep crater "Zola" with coordinates 50°/180°. Then the merkuromobil path passes through crater Strinberg, which diameter is 150 km. Having covered during the second research expedition of about 1600 km, the astronauts in 6 days return to the base, located on the plateau "Shakespeare"

The last stage of the research program- the launch of orbital space laboratory. For the first time a project of orbital space laboratory was designed for an expedition towards the planet Venus [5]. In this project the basic design remains the same as in the laboratory designated for launching into orbit of Venus. But the composition of devices, which are necessary for monitoring of the processes on Mercury surface, is changed. Instrumental equipment is complemented with magnetometers and with devices to measure the strength of the solar wind.

After completion of the research program, the crew of the expedition takes their seats in the cabin of the takeoff-landing capsule.

The chemical rocket engine 6 is switched on (Fig. 3). The takeoff-landing capsule takes off from the surface of Mercury and goes into the Mercury orbit, across which moves the locomotive 1, connected with full tank-container 2.

By means of the maneuvering with the help of chemical rocket engine 6, the connection of the capsule 3 and the rocket train is carried out using the docking assemble 5.

The system of artificial gravity capsule is switched on. The space train starts the flight from orbit of Mercury towards the Earth orbit. The electrorocket engines 4 of locomotive are switched on. When speed of the train becomes 4.3 km/s, it leaves the orbit of Mercury and begins to move along the calculated trajectory, as shown in Fig. 4.

In a day of flight, being at a distance of 30 thousand km from the surface of Mercury, the astronauts observe and photograph the comet-shaped tail of Mercury.

At Fig. 4 one can see that at the beginning of the stay onto orbit of Mercury the space train is at the point 2. During the stay on Mercury the planet itself has moved across orbit around the Sun from the point 2 to the point 3. During the same time Earth has moved across the orbit around the Sun from the point 2' into the point 3'.

During the flight from the orbit of Mercury onto Earth orbit the space train should pass along the calculated trajectory from the point 3 into the point 4 ', where at this moment already would be Earth.

Let's see how passes the process of the space train movement in time , shown in Fig. 5.

During 10 days the space train is accelerating up to the speed of 200 km/s, while having initial weight of 48 tons. Next, during 2 days the flight continues by inertia with switched off electrorocket engines (Fig. 3).

After that, the direction of the thrust of the electrorocket engine changes on 180 degrees. The engines are switched on and the braking of the space train, which lasts 7 days, begins. The return flight from the orbit of Mercury onto the Earth's orbit takes 20 days.

After entering into the Earth orbit the decoupling of the space train occurs. Locomotive 1 continues the motion along circumterrestrial orbit in expectation of the new formation of the train for the next flight towards a planet of the solar system.

The tank-container 2 also remains in Earth orbit and after refilling with liquid hydrogen is used for new interorbital flights.

The takeoff-landing capsule 3 with the crew using chemical rocket engine 6 goes into orbit of the international orbital space station. The crew taxis the capsule to a moorage of the orbital space station and docks it. The crew of the expedition leaves the takeoff-landing capsule and passes into the orbital space station.

In this way ends the expedition to the planet Mercury, which lasted 56 days.

And now let us estimate how much means will be required for the conduction of the expedition?

For the preliminary flight it is required to launch two tanks-containers 3 and 4, as well the refueller 7, which are shown on Fig. 1.

As the locomotive 1 can be used the locomotive, which regularly makes flights from Earth orbit into the orbit of Mars [3]. The cost of three launches making use the carrier rocket "Delta 4 Heavy " will amount to 600 million dollars [6].

For the implementation of the basic flight it is necessary to carry out the launch of the orbital space laboratory 2 (fig. 3). The cost of this launching while using the carrier rocket " Delta 4 Heavy " amounts 200 million. dollars too.

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The main costs will be required for the manufacturing of space refueller and merkuromobil, which according a preliminary estimation can reach 1200 million dollars. Thus the total cost of the expedition will be 2000 million dollars.

II. The Space Refueller

The space refueller is intended for the delivery of liquid hydrogen and liquid oxygen on the surface of Mercury. Hydrogen is used as fuel and oxygen as oxidant for chemical rocket engine which is installed in takeoff-landing capsule in which is the cabin crew of the expedition. In addition, the oxygen and hydrogen are used in the fuel cells, which are installed on the mobile device - merkuromobil. The design of the refueller is shown in Fig.8.

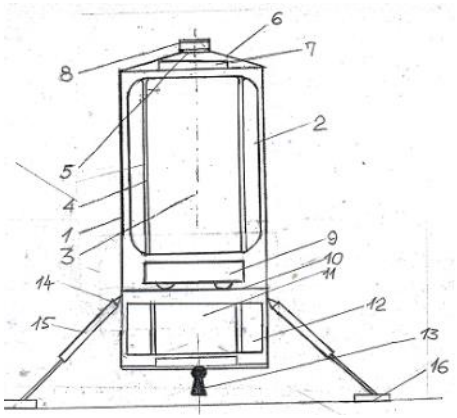

Fig. 8

The refueller 1 has a body made of aluminium alloy. Inside the case is tank 2 with liquid oxygen, which has screen-vacuum insulation. Inside a hollow cylindrical tank 2 is located a cylindrical tank with liquid hydrogen 3. Between the tanks 2 and 3 there is a vacuum gap 4.

The docking assemble 5 serves for connection to tank-container in the process of the space train formation during the preliminary flight. Inside a cone-shaped part 6 of the body a container 7 of cylindrical form is located, in which hosts the soft landing control system of the refueller with the help of chemical rocket engine 13.

The chemical rocket engine 13 has a separate tank 11 with fuel- hydrogen and a tank with oxidant - oxygen. Between tanks 2,3 and tanks 11,12 there is a separating bottom 10, on which the merkuromobil 9 is installed.

The space refueller permits to deliver merkuromobil on the surface of the planet. Installation of the refueller on the surface of Mercury is carried out using retractable uprights 14 , which have shock-absorbers 15 and shoes 16.

As calculations show, to conduct the expedition, first of all, it is necessary to have enough fuel and oxidant for takeoff of the landing capsule with crew from the surface of Mercury. For this purpose 11 tons of fuel and oxidizer is consumed. The mass of the fuel and oxidizer, which is consumed at landing of the refueller itself on the surface of Mercury with the help of chemical rocket engine 13 is 6 tons. The mass of the fuel and oxidizer for movement of the crew across the surface of Mercury is 4 tons. Thus, the total mass of tanks 2, 3, 11 i12, filled with liquid components, is 21 ton.

III. Merkuromobil

Merkuromobil is intended for movement of the expedition crew on the Mercury surface. It is a car with electric drive. It is designated for 6- day of mobile stay of two passengers and is equipped with navigation devices, portable drill installation for taking samples of soil from the surface of Mercury and a system for TV image transfer.

The design of merkuromobil is shown in Fig. 9..

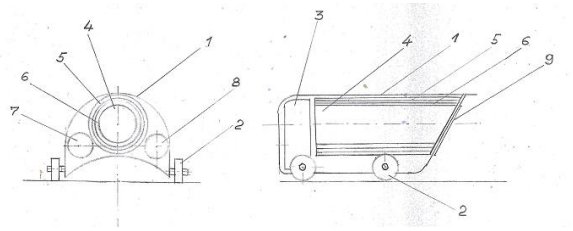

Fig.. 9

The outer casing 1 is made from ultrastrong light material-carbon. To the outer casing motorized-wheel 2 is fastened using shock absorbers. In this project a new design of cryogenic motorized wheel with a superconducting bearing without friction was developed.

The merkuromobil moves with the help of four motorized wheels, on each of which one can create a torque of the required size and direction. Automatized control of the motorized wheels is performed using a frequency converter. Energy supply for the motorized wheels is provided by a battery of hydrogen-oxygen fuel cells 3. The fuel components in liquid form are stored in the tank 7 with liquid hydrogen with and in the tank 8 with liquid oxygen.

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When designing the merkuromobil the special attention was drawn to protection of astronauts from the solar wind and cosmic radiation. One should not forget that on the surface of mercury is missing protective atmospheric layer, as on Earth, and the intensity of magnetic field in 100 times less than on Earth.

Inside of the merkuromobil the cylindrical cabin 4 is located. Outside of the cabin a tank 6 in the form of a hollow cylinder is located , which is filled with liquid hydrogen. And outside of the tank 6 another hollow cylinder 5 is located ,which is filled with liquid oxygen.

To protect the the cabin from the charged particles inside the tank 6 the solenoid is installed, which creates a constant axial magnetic field. The winding of the solenoid is made of superconductor-magnesium boron. Protection of astronauts from cosmic radiation is carried out due to a layer of liquid oxygen and liquid hydrogen in tanks 5 and 6.

Inside the cabin 4 of astronauts the personal service premises are located : toilet, shower, kitchen, etc. (by analogy with the similar automobile premises on Earth)).

As a result of action of the fuel cells water is produced, which is used for domestic purposes. The astronauts go out on the Mercury surface through the front hatch, which has a window for observing the surface of Mercury.

The main parameters of merkuromobil:

1. Dimensions: Length-4 m Width-3.5 m Height 2 m
2. Payload – 300 kg
3. Fuel an oxidizer consumption -50 kg per 100 km
4. Weight with empty tanks-800 kg
5. Weight after refueling -1800 kg
6 Maximum speed is 40 km/h.
7. Power consumption -20 kW

IV. Cryogenic Motorized Wheel

Cryogenic motorized wheel is intended for movement of the merkuromobil. Works on the principle of the synchronous AC powered motor. Energy source is the fuel cell, combined with a frequency converter. The design of motorized wheel is shown in Fig. 10.

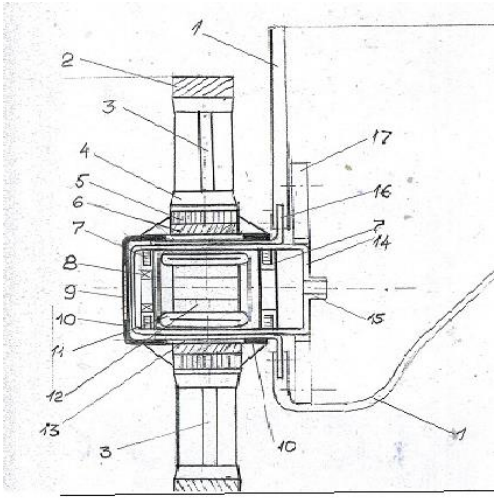

Fig. 10

Motorized wheel consists of the outer rim 2, which using spokes 3 is connected with the hub 4. The movable part of the motorized wheel is the rotor of the electric motor. It has a magnetic system consisting of permanent magnets 6 made of alloy iron -neodymium boron.

On the outside the permanent magnets 6 are sealed in a annular magnetic core made of sheets of electrical steel. Inside of the inductor 6 a rotating wheel 10, also consisting of permanent magnets, is located.

The fixed armature 12 of the motor is located on the horizontal axis of the wheel. The armature has three-phase winding 11 made of superconductor magnesium boron. For the operation of superconductors the armature 12 is placed in cryostat 14 made of fiberglass and having a cylindrical shape. In the internal cavity of the cryostat there are two cylindrical rings 7 made from a solid massive superconductor. To create the axial thrust holding the wheel in a magnetic bearing, a cylindrical magnet 8 with superconducting winding. is installed. Cryostat 14 enshrines in casing of the merkuromobil 1 using the fiberglass cylinder 16.

The motorized wheel operates in the following way. Liquid hydrogen enters into the cryostat 14 through the neck 15.

In this case all superconducting elements of the motorized wheel: superconducting winding of the electromotor 11 armature, cylindrical rings of the bearing 7 and the winding of electromagnet 8 are put in working condition. When cooling of the hard superconductor 7, the force interaction between stator and rotor of the motorized wheel, known as Meissner effect, arises.

The magnetic field of the permanent magnets cannot penetrate deep into the space occupied by the hard superconductor in the rings 7.

Hereupon a lifting force arises and the rotor of the motorized wheel begins to " hang", creating a gap 13 between the stator and the rotor. When submitting a current in the armature winding 11 a rotating magnetic field is created that interacts with the field of the permanent magnets 6. The torque moment on the wheel rim 2 arises.

Using a frequency converter the frequency of the current in the winding anchor 11 is increased. The number of revolutions of motorized wheel increases, increasing the speed of the merkuromobil movement.

Owing to the interaction of the permanent electromagnet 8 and the ferromagnetic core 9 an axial force is created, which keeps the superconducting bearing.

The cryogenic motorized wheel, which is developed in the project has no friction parts, allowing the damping of the blows that occur when movement of the merkuromobil and to overcome the bumps on the surface of Mercury.

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