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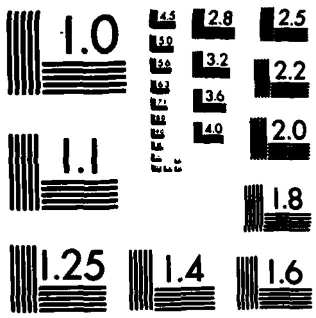

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FTD-ID(RS)T-1228-82

FOREIGN TECHNOLOGY DIVISION

AERONAUTICAL KNOWLEDGE

(Selected Articles)

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FIRST FLIGHT TEST OF CHINESE ELECTRON ROCKET IS SUCCESSFUL

New China News Agency wire, Beijing, Jan. 13. A Chinese developed electron rocket recently carried out a successful space flight test.

The two pulse plasma engines, which were developed by the Electron Propulsion Research Laboratory of the Space Science and Technology Center of the Chinese Academy of Sciences, under vigorous cooperation of the sectors involved, successfully carried out its first space flight test. The success of this flight test indicates that China's electron rocket research work has entered a new stage and enables China to have a new type of microthrust space rocket engine.

The electron rocket features low thrust, high specific impulse, long service life, rapid actuation, and maneuverable control. It is suitable for attitude control and orbital corrections of various types of satellites and spacecraft.

At present, a number of countries are conducting research on many types of electron rockets, one of which is the pulse plasma engine. Both the United States and the Soviet Union began space tests on this type of engine in the 1960s and it has gradually obtained space applications. Japan also launched research into this area and has conducted space tests. China is the fourth country to conduct space flight tests with the electron rocket. The objective of this test was primarily to verify the operating conditions of the entire electron rocket system in an actual space environment, to confirm the results of ground-based experimental research, and to learn more about the effect of the electron rocket on other systems, thus advancing the research and applications of this new technology a step further. During this flight test, according to the assessment of telemetry results, the two engines operated normally and the entire test achieved the desired results.

THE PLASMA POWERPLANT

Song Yuyang

After the successful launch of the first artificial earth satellite in October, 1957, various types of satellites and spacecraft have been launch one after another. Along with the development of scientific technology a number of new types of powerplants have appeared in space one by one. The plasma engine is one of them.

WHAT IS A PLASMA ENGINE?

What is a plasma engine? Before talking about the plasma engine, let's first discuss what plasma is.

Plasma is a kind of ionized gas. When electrons bombard a gas the molecules are ionized. If electrons are lost it will change into positively charges ions. For example:

$$H_2 + e = H_2^+ + 2e$$
$$H_2 + e = H^+ + H + 2e$$

therefore, plasma is a mixture which is composed of charged ions, electrons, and neutral particles and which macroscopically manifests electrical neutrality.

In plasma engines for space the plasma is usually produced from a gas or a vaporized solid-state dielectric material.

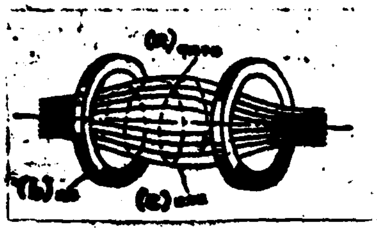

Fig. 1. Using magnetic fields to confine plasma

KEY: (a) plasma; (b) coil; (c) magnetic lines of force

In order to ionize the working medium to produce plasma, the working medium must be heated to a temperature where the mean kinetic energy of the atoms is greater than the ionization energy. For hydrogen and deuterium the above mentioned temperature is $160{,}000^{o}$K. Such high temperatures cannot possibly be endured by presently existing materials. However, in a plasma, since the electrons and ions are both in equilibrium the actual temperature will be somewhat lower. In order for the operation of an engine to be reliable, magnetic fields are normally used to confine the plasma (as shown in Fig. 1.) which prevents the high temperature plasma from coming into direct contact with the chamber walls.

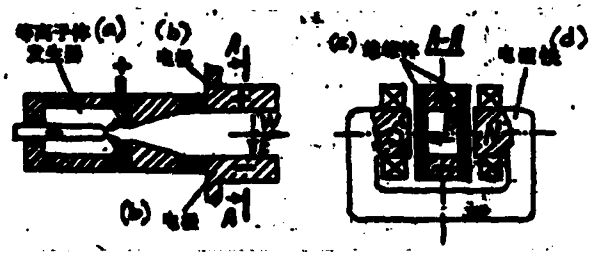

Fig. 2. Diagram of the operating principles of a plasma engine

KEY: (a) plasma generator; (b) electrode; (c) insulators; (d) electromagnet

Figure 2 is a diagram of the principles of operation of a plasma engine. It is composed of two electrodes - a cathode and an anode. The electodes and the electrically insulated sidewalls form a plasma channel. This channel, on the one hand, is perpendicular to a magnetic field with an electric field intensity of $\overline{E}$ and, on the other hand, is penetrated by a magnetic current of inductance $\overline{B}$, which is produced by the electromagnet. The plasma is produced in the plasma generator and then enters the accelerator. Since the plasma is a charged gas, in the accelerator the current travels from the cathode through the plasma to the anode. Under the effects of the electric and magnetic fields the plasma produces an ampere force and is ejected at high speed through the accelerator outlet, producing a reactive thrust. In this type of engine, since achieving the conversion of electrical energy into kinetic energy is dependent on the plasma (the working medium), we call it a "plasma engine".

THE POWER UNIT

A plasma powerplant consists of two main components: the plasma engine and the power unit. The former produces reactive thrust, the latter supplies electrical energy. Electrical power supply for satellites and spacecraft is also provided by power units. At present, power units of 5~50kW can already be built abroad for spacecraft. There are two types of power units used for plasma engines. One type is the nuclear power unit, the other is the solar power unit.

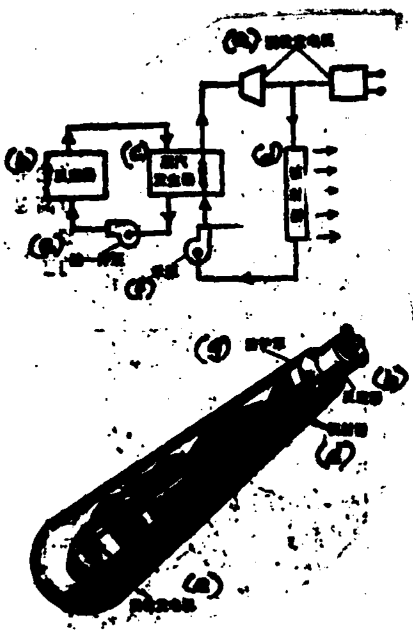

Fig. 3. SNAP-2 power unit and diagram of operation

KEY: (a) turbogenerator; (b) reactor; (c) vapor generator; (d) radiator; (e) sodium-potassium pump; (f) mercury pump; (g) protective shielding

Figure 3 is a SNAP-2 power unit. Figure 3 (top) is a functional diagram of it. Figure 3 (bottom) is a diagram of its outward appearance. This is a double circuit system. The first circuit employs sodium-potassium alloy (melting point is -11°C, boiling point is 784°C at 10^5Pa pressure) as the heat transfer medium; the second circuit uses mercury as the working medium. When the sodium-potassium alloy comes out of the reactor its temperature is 650°C. It then enters the vapor generator, is heated, and since the boiling point of mercury is 357°C at 10^5Pa pressure, after being heated in the generator it changes from a liquid to a gas and the mercury vapor (pressure 700kPa, temperature 620°C) enters the turbine, causing the turbine to rotate (40,000rpm), producing 3kW of electrical power. The Hg vapor exhausted from the turbine enters the radiator and after being cooled changes into a liquid (pressure 42kPa, temperature 315°C). After passing through the mercury pump, the mercury is then transferred to the vapor generator. The entire power unit weighs 345kg without shielding.

Because of the nuclear fuel there is a critical mass problem. Therefore, a low power plasma engine normally employs a solar power unit.

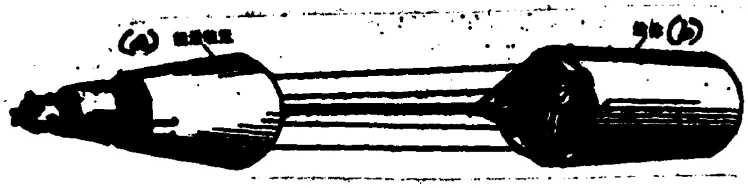

Fig. 4. Location of SNAP-2 power unit in spacecraft
KEY: (a) power unit; (b) crew compartment

As for manned spacecraft, for safety purposes a certain distance must be maintained between the nuclear power unit and the crew compartment. Figure 4 shows the location of the power unit in a spacecraft. This is a 25kW power unit which weighs 3600kg without shielding. The weight of the shielding is 2000kg and the distance between the power unit and the crew compartment is 15m. Figure 5 is another type of power unit.

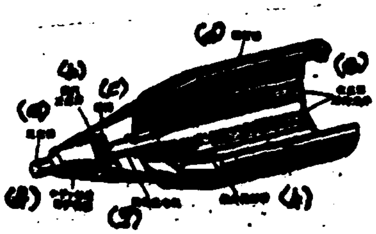

Fig. 5. Structural diagram of a power unit
KEY: (a) reactor; (b) vapor generator; (c) (illegible); (d) radiator; (e) structural elements of collector; (f) neutron γ-ray shielding; (g) turbogenerator; (h) thrust controllers

CHARACTERISTICS AND APPLICATIONS

Plasma engines have the following characteristics:

1. High specific impulse (10^2 - 10^4 seconds);

2. Low thrust (10^{-3} - 10 newtons);
3. Long operating time;
4. Can be started many times;
5. Low efficiency;
6. Thrust-to-weight ratio less than 1.

The last point means that for space flight the plasma engine must first rely on another power unit (such as a solid or liquid rocket engine) to go into orbit and then be able to go into operation. Since space flight does not require high thrust, this type of engine is suitable for maintaining the position, for attitude control, and for orbital corrections of satellites, spacecraft, and space stations.

Serving as low thrust power units with long operating t[illegible]s, the plasma engine has obvious advantages. For example, a chem[illegible]l fuel rocket engine with a thrust of 0.01kg and an operating time [illegible] one year must carry 1240kg of high energy fuel for a specific [illegible]se of 250 seconds. After adding the weight of the engine housing [illegible]d accessories, the entire powerplant will weigh several tons. Under the same conditions, the weight of a plasma powerplant will be much lighter and its operation will be quite reliable.

Plasma engines are divided into two major types according to the difference in functional principles: the continuous operation type and the pulse type. The former does not have such components as capacitors and is therefore relatively simple. In 1961, the Soviet Union launched the "Meteor" artificial earth satellite equipped with two continuous operation type plasma engines, each with a thrust of 0.02 newtons. In February, 1972, the satellite was shifted to a synchronous orbit by the use of these plasma engines.

At present, ablation type pulse plasma engines have obtained fairly widespread use in space. In this type of engine an easily vaporized solid-state dielectric, such as polytetrafluoroethylene, is used for the working medium. When the capacitors are discharged, this type of material is heated and vaporized, causing erosion. The vaporized gaseous material is at the same time ionized and under the effects of the electric and magnetic fields is ejected at high velocity from the engine outlet, producing thrust.

In December, 1964, the Soviet Union launched the "Zond 2" automatic planetary station toward Mars (height above the earth's surface 5,370,000km), which for the first time used six ablation type pulse plasma engines for orientation. The engines were controlled by signals and changed operation on command and for a given time maintained the bearing of the space station with respect to the sun.

In 1968, when the United States launched the Lincoln Experimental Satellite 6, it was equipped with six ablation type pulse plasma engines built by the Fairchild Company, which were used to maintain the satellite's position in an east-west direction. When each engine operated there was a six second pulse cycle. When four engines operated in series the pulse duration was 1.5 seconds. Each engine was estimated to be able to discharge 12 X 10^6 times, each discharge producing a thrust of 2mg, which would enable it to operate in space for two years. Recently, two pulse plasma engines developed by China were successfully flight tested for the first time, which indicates that the development of Chinese rockets has entered a new stage, enabling China to be the fourth country in the world to conduct space flight tests of electron rockets.