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Modern spacecraft thermal control systems

Nowadays in the world there are many space programs to create a variety of spacecrafts. Many equipments should be located on its board. It is necessary to keep a normal thermal condition that the equipment operates without failure. The normal thermal condition of a technical system is called such a mode when the temperatures of all materials and components do not exceed the specification boundaries at all operating conditions, which are listed in the technical task.

Thermal conditions of a technical system depend on disturbing influence factors. The factors are listed in the GOST RV 20.39.304-98 "Complex system of general technical requirements. Military apparatus, instruments, devices and equipments. Requirements of resistance to external factors". In this standard all apparatuses shared between the four groups: 5.1–5.4. Functions and operating conditions of an apparatus are the sign at defining a group.

An apparatus locating into domestic and improved protected compartments of a spacecraft refers to the 5.1 group. An apparatus locating into sealed instrument compartments of a spacecraft refers to the 5.2 group. An apparatus locating into spacecraft unpressurised compartments or on spacecraft external surfaces with used protection measures refers to the 5.3 group. An apparatus locating on spacecraft external surfaces without used protection measures refers to the 5.4 group.

Tendency of a modern spacecraft development is aimed at reduction in weight and size, decrease power consumption, multifunctional, decrease development and production time and cost. The tendency cause to new spacecraft creating principle based on unpressurized unit. Therefore, modern spacecraft equipment belongs to the 5.3 or 5.4 groups.

Spacecrafts are used both on the ground and in space conditions. On the Earth a spacecraft exposed disturbing factors on the tasting, transportation and storage stages. The space conditions include the following stages of operation: orbiting; orbital flight; launching from an intermediate orbit; flight on a track; orientation, maneuvers, correction, docking in orbit or a track; braking, dropping, landing; operate on a planet surface of the solar system and the moon; launch from planets of the solar system and the moon.

Therefore, space conditions such are different as conditions of the Solar system planets are various. Unfortunately, the standard provides very little information about thermal conditions, which listing in table 1.

Table 1

Space thermal conditions from GOST RV 20.39.304-98

External factor	External factor characteristic	External factor value	
		5.3	5.4
Higher ambient temperature	Operation, °*C* (*K*)	50 (323)	125 (398)
	Critical, °*C* (*K*)	60 (333)	125 (398)
Reduced ambient temperature	Operation, °*C* (*K*)	minus 50 (223)	minus 150 (123)
	Critical, °*C* (*K*)	minus 50 (223)	minus 150 (123)
Solar radiation	Integrated density flow, W/m^2	–	1400

*5.3, 5.4 are the groups of apparatuses

The data from the standard needs in addition. For instance, On Mercury and Venus ambient temperatures may be higher than critical higher ambient temperature for 5.4 group. According to the infrared measurement illuminated surfaces temperature of Mercury and Venus accommodation equal 611 K and 743 K [8, p. 976]. But conditions of a planet are specified factors which taken into account when a spacecraft is designed for rare special programs.

Creators of a regular spacecraft are important to know values of radiations from Solar and other object of the Solar system. For example, Earth thermal radiation power is equal 225 W/m^2 [9].

Also technogenic factors can to influence on equipment in space. These factors arise from an operation of the apparatuses or a nearby spacecraft [5].

A temperature field of a technical system is a temperature values collection of all points in the system at any time. This field characterizes a thermal mode. The latter should be evaluated at the development. It is necessary to create a thermal processes model based on the external factors. Thereafter it is possible to set analyzing and creating tasks for a thermal control system [3].

A thermal control system (TCS) is one or more devices which used to achieve the normal thermal mode. TCS devices can to operate due to different physical and chemical principles. The devices can be considered as active and passive by the power consumption. Also these devices can be considered as heat transfer systems, thermo insulation systems, heat dropping systems, heaters and coolers by functionality.

Several instances of spacecraft TCS devices are given from [2]. Conductive cooling systems, heat exchangers and heat pipes are the heat transfer systems. Radiation cooling systems and space radiator in other words are the heat dropping systems. Evaporative cooling systems, vortex tubes, gas expansion machines and thermoelectric devices (Peltier elements). In addition the examples, multi-layer heat shield and electric current heater are used together in the system [9]. It is also possible to create TCS with used next physical and chemical effects: infrared radiation, conversion of mechanical energy to heat (for instance, by friction), exothermic and endothermic chemical reactions.

There are points with emission and absorption of heat in spacecraft equipment. The heat emission sources locate into spacecraft as a rule. The heat leak sources are outer exposed surfaces. However, outer exposed surfaces absorb a part of the solar, planets and moons electrical magnetic radiations.

Therefore, high-performance TCS creating for a modern spacecraft has next trends:

- increasing outer exposed surfaces or using space radiators;
- using high-emitting materials for space radiators surfaces;
- decreasing electrical magnetic radiations absorbing surfaces and using low-absorptance materials;
- development special Sun tracking systems or other electrical magnetic radiations sources;
- providing high-performance heat transfer between the points with emission and absorption of heat.

In modern spacecraft development fixed space radiators with using thermal pipes [6] are common TCS. Flexible deployable-retractable space radiators [4] are used in TCS of high-energy spacecraft such as the International Space Station. Cascaded heat pipes are used in precise satellite thermal control systems [7]. Flat thermal pipes are often used in heat load electronic cells [1].

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