

Spacecraft protection from the negative effects of environmental factors and complex dynamic loads at the transportation stage

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Abstract. A paper presents a design version of the specialized container for transporting a spacecraft to a launch site. The goal is to ensure the safety of the spacecraft’s technical characteristics in the specialized container by meeting the requirements for temperature, humidity, air purity and dynamic loads. The developed version corresponds to the modern level of technology development and allows specialized containers development of any size in a short time. This design version of the specialized container provides the desired comfort conditions for a spacecraft during a prolonged impact to negative environmental factors.

1. Introduction

One of the key consumer requirements for spacecraft of the communication, geodesy, navigation, military and dual-purpose is duration of the useful life. It is necessary to keep the specified technical characteristics of the spacecraft in order to ensure the required period of the useful life including the transportation stage of the spacecraft from the manufacturer to the launch site, as the transportation stage a spacecraft is under dynamic impact as well of negative environmental factors in the process of spacecraft developing. In order to ensure the safety of the spacecraft’s technical characteristics, the transportation to the launch site is carried out in a specialized container (hereinafter refers as SC).

It provides comfortable conditions for a spacecraft taking into account temperature, humidity, air purity and dynamic loads [1].

A specialized transportation container for a spacecraft is known. It includes a base with a body, mooring and rigging nodes, a supporting unit for a spacecraft fixed to the base under the body [2]. Lifting and moving of this transportation container inside any constructions is possible only with the crane equipment (or manually - with a small weight of the shipping container). A transportation container that includes a base with a body, running wheels, mooring and rigging nodes, a support unit for a spacecraft fixed to the base under the body has already been known [3]. Moving of this transportation container inside any construction is possible both using crane equipment and their own running wheels.

2. Formulation of the problem

At present, due to the constantly increasing nomenclature of launched spacecraft and the reduction in



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their mass and dimensional characteristics, in the preparation of spacecraft at the space center, mainly portable (i.e. returned to the manufacturing plant after launching) ground processing equipment are used [1]. At the same time, the composition of the portable ground-based technological equipment of the spacecraft is quite extensive and, in general, includes: check electrical equipment; equipment for charging on-board batteries; mechanisms for mechanical system depreciation; technological stands; refueling equipment; rigging equipment; facilities.

Each type of the equipment mentioned above (and often its individual units) has its own transport packaging (container, box, cover, etc.). In addition, in separate containers sent by the manufacturer to the spaceport all components, consumables, necessary for work with the spacecraft are delivered.

Thus, the delivery to the spaceport, in addition to the specialized container with a spacecraft, is a subject to a significant number of individual containers; most of them are returned to the manufacturer.

At the aviation transportation of a spacecraft from the manufacturer to the launch site, not only an aircraft but also any vehicle is actually used in the route of transportation (delivery of the transported cargo from the manufacturer to the aircraft and also from the aircraft to the assembly and testing constructions of the spaceport).

When the space vehicle is transported to the spaceport by rail, it is also possible to use not only a railway vehicle, but also motor transport (delivery of transported cargo to the car, delivery of transported cargo from the car to the storage facility, etc.) along the route.

The use of different types of vehicles along the route leads to the necessity for the repeated loading (unloading) and fastening (detaching) of transported containers with the ground technological equipment. As a result, the duration and laboriousness of loading and unloading operations increases.

Thus, the shortage of the considered transportation containers is the impossibility of its application for transportation together with containers with ground technological equipment necessary for the preparation of the spacecraft at the spaceport.

In general, when transporting a spacecraft, the following comfort conditions are required:

- air temperature is from plus 5 to plus 35 ° C;
- relative humidity is not more than 60 %;
- air purity corresponds to the cleanliness class 8 ISO according to GOST ISO 14644-1-2002;
- reduce of the dynamic loads to an acceptable level (threshold level up to 3g).

To maintain comfortable conditions in the SC, various systems are provided. Their functioning ensures that a required parameter is located within a specified range.

3. Methods to protect the spacecraft from the negative impact of the environment

Let's consider the implementation of methods for spacecraft protection from the negative impact of the environment during the transportation of spacecraft in the SC.

To ensure comfortable conditions for temperature in the spacecraft passive and active means of ensuring the temperature regime (hereinafter refers as METR) are provided. As passive METR constructive solutions are used that ensure the given thermo and physical characteristics of the SC.

To ensure the specified thermo physical characteristics of the spacecraft development of the JSC "ISS", heat-insulating materials glued to the internal surfaces of the spacecraft were used. The disadvantage of this method is the deterioration of the adhesive strength of the adhesive layer with the subsequent peeling of the thermal insulation material during long-term operation of the spacecraft.

At present, heat-insulating panels are used as passive METRs. They are a frame made of a metal profile where an aluminum sheet casing with the interior space being filled with heat-insulating material with a low coefficient of thermal conductivity is fixed. The key advantages of thermal insulation panels are high rigidity of the spacecraft design and low thermal conductivity, durability.

As useful METR inside the spacecraft, the basic and reserve air-heating and air-cooling units are used, structurally located inside the spacecraft; a control unit and a compressor-condenser unit of the air-cooling unit are located outside the spacecraft. This solution gives the opportunity to use the internal space of the SC efficiently, provides convenience in its operation, and hot backup of the executive devices guarantees the reliability of the SC as a whole. Thermostating of the internal volume of the SC

is carried out by air circulating in a closed loop that automatically heats up or cools, depending on the ambient temperature.

To ensure comfortable conditions for humidity and maintain air purity corresponding to the cleanliness class 8 ISO in accordance with GOST ISO 14644-1-2002 in the SC is initially provided by the packaging of the spacecraft in a sealed SC prepared for the transportation in the space with a class of cleanliness not less than 8 ISO according to GOST ISO 14644-1 -2002.

To ensure comfortable conditions for humidity and maintain air purity during transportation, the following solutions can be provided in the design of the SC: laying of silica gel inside the SC. This version is positively aimed at maintaining the required humidity within the SC. However, it is irrational due to the fact that the silica gel deteriorates the air purity and requires the use of woven dust-proof bags meeting the requirements for air permeability; maintaining excessive pressure in the SC, preventing the ingress of foreign particles into the interior, by using a block of cylinders with compressed dried air and a pressure reducing valve mounted inside the SC. This version is positively aimed at maintaining the required humidity and air purity, however, it involves the use of a cylinder block in the SC design; it entails an increase in SC weight, a decrease in the payload zone inside the SC or an increase in the SC dimensions. Also there exists a risk of exhausting the entire air volume from a block of cylinders in the event of a significant increase in the time of transportation due to any unforeseen circumstances; use of a special external compartment with an air filtration system based on highly efficient filter elements communicating with the internal volume of the SC. This version implies placement in the SC design of a unit containing, as a rule, bags with silica gel and filters with different adsorption parameters and simultaneously providing the necessary capacity.

The principle of operation is based on the use of natural air convection and includes 3 stages:

- 1) adsorption by silica gel of moisture contained in the air;
- 2) adsorption by a carbon filter of volatile and semi-volatile gaseous organic compounds;
- 3) fine air purification HEPA-filter class not lower than 14 (figure 1).

The key advantages of the air filtration system based on high-efficiency filter elements are high degree of air purification and absence of maintenance necessity during transportation, simplicity of implementation and high reliability [4].

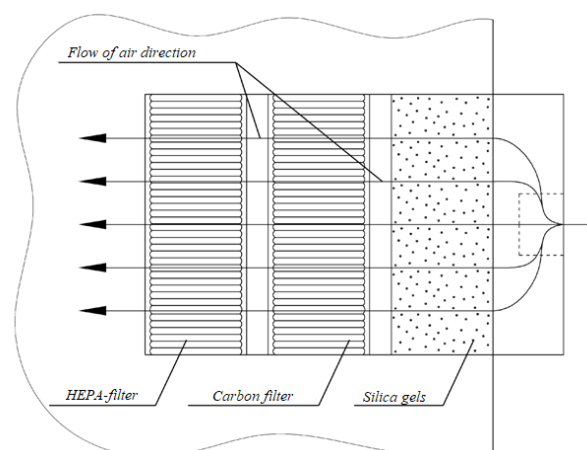


Figure 1. Air filtration system based on highly efficient filter elements.

A seal assembly for a cover joint with the SC base to ensure leak-tightness of the SC when it is opening/closing multiple times and, accordingly and to maintain high purity of air inside the SC while

transporting it in the SC was developed. It consists of the main monolithic sealant and an additional hollow sealant with the help of the positioning elements provided in it [5].

4. Methods of protection of spacecraft from the impact of dynamic loads

To protect a spacecraft from the effects of dynamic loads (vibration, shock loads, acoustic vibrations), a specified speed regime is provided (for example, by road transport on the roads of categories I-III at a speed of no more than 60 km/h and / or on the roads of IV-V categories with a speed of no more than 20 km/h) or the use of vibration-proof means, for example, an amortization platform amortization platform (figure 2).

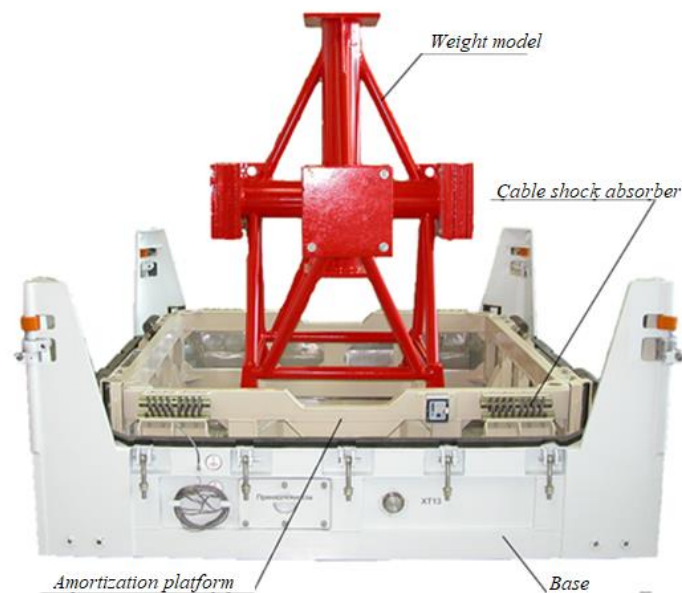


Figure 2. General view of the amortization platform.

The use of an amortization platform will reduce the negative impact of dynamic loads to an acceptable level without resorting to a compulsory reduction in the permissible possible speed of transport the movement carrying out transportation [6].

The placement of the shock-absorbing platform inside the SC is optimal, since in the case of using an external damping system, the weight of the object to be inspected increases and, as a consequence, the load-carrying capacity of the depreciation system is required, the range of possible SC mounting options on vehicles is also narrowed.

Currently, various means of damping dynamic loads, successfully used in various fields of technology are used. Some versions of the design of shock absorbers and their general characteristics considered in relation to the protection of spacecraft from the impact of dynamic loads.

Let's consider rubber-metal shock absorbers. Their disadvantages are large weight and size characteristics, short service life, exposure to external influences (temperature, aggressive media, etc.), low dynamic factors and high natural frequency of oscillations.

Shock-absorbers are assembly and composite. Disadvantages of such shock absorbers are sufficiently large weight and size characteristics, high labor input in manufacturing and a relatively high cost.

Metal shock absorbers with resilient damping elements made of metal knob. Their disadvantages are high labor input in manufacturing, high weight and size characteristics and a short service life.

The scientific and practical experience accumulated in JSC "ISS" during ground-based operation of spacecraft and their payload [4-6] allows us to confidently say that the most effective way to protect them from the negative impact of dynamic loads arising during transportation is to use the design SC amortization platforms based on cable shock absorbers. Cable shock absorbers are chosen for a number

of advantages, in comparison with other types of shock absorbers, the main of them are: more effective damping of the dynamic load in cable shock absorbers; cable shock absorbers have smaller weight and size characteristics; it is very important taking into account the carrier's limitations in the size of transportation containers.

To monitor and record the parameters of transportation conditions (temperature, humidity, dynamic loads), the equipment for monitoring and recording parameters of transportation conditions is provided. It consists of sensors mounted both inside the SC and outside.

5. Conclusion

Thus, the preferred embodiment of the SC design for protecting a spacecraft from the negative effects of the environment and dynamic loads during the transportation phase is:

- body made of heat-insulating panels;
- placement of METR actuators inside the SC;
- passive air filtration system based on highly efficient filter elements;
- amortization platform based on cable shock absorbers.

The described version of spacecraft design corresponds to the modern level of technology development and allows spacecraft design of any size in a short time. This version of spacecraft design provides the given comfortable conditions for a spacecraft during a prolonged impact to negative environmental factors.

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