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Technical requirements of contamination control for satellite

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Technical requirements of contamination control for satellite

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FOREWORD

The standard is translated from the Chinese version of Standard on GB/T 29085-2012 released by Standardization Administration of China (SAC) under the management of State General Administration of Quality Supervision and Inspection and Quarantine. TC 425 is responsible for the translation. In case of any doubt about the contents of English version, the Chinese original shall be considered authoritative.

This standard is drafted in accordance with rules given in GB/T 1.1-2009.

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INTRODUCTION

This standard belongs to the National Standard System of China Space. The National Standard System of China Space is applicable to the formulation, revision, and management of national standards in the field of space, covering three sectors of space management, space technology, and space application and services and serving as the basis for guiding spacecraft and launch vehicle project management, engineering, space launch services, and in-orbit satellite applications.

With the developments of satellite research and manufacture technology as well as the requirements of national defense and economy, it is required that satellite shall have more precise and complex optical, thermal control, navigation positioning control and longer service life. Contamination is an important factor affecting the reliability and safety of satellite products. The contamination accumulation effect for a long period will affect the performance of satellite and its payloads and then shorten the service life of satellite and its payloads. Therefore, it is necessary to carry out contamination control for all aspects in the research and manufacture of satellite products.

Technical requirements of contamination control for satellite

1 Scope

This standard specifies each item of contamination control necessary for the overall process of satellite development and its technical requirements.

This standard is applicable to the development of satellite system, and is also applicable for the reference of subsystems and components (including devices and parts).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB 50073-2001 Specification for design of cleaning plant

ASTM/E 595-1993 Standard test method for total mass loss and collected volatile condensable material from outgassing in a vacuum environment

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

contaminant

unwanted foreign material which will cause damage and influence that cannot be negligible to the reliability and performance of system, subsystem, device, component and material.

3.2

particulate, particulate matter and particle

observable granular solid material (including fiber) with the length, width and thickness sized 0.001μm~1000μm.

3.3

non-volatile residue

NVR

a soluble substance retained by volatile liquid after volatilization or a non-volatile matter determined by special analytical instrument. It is usually measured with the milligrams of contaminants per unit volume or per unit area.

3.4

volatile condensable material

VCM

a gaseous substance which is desorbed, separated or decomposed from components, materials, or

contamination sources, and can be condensed on the low-temperature surface under the condition of high temperature, low pressure and vacuum.

3.5

collected volatile condensable material

CVCM

for material sampling under the condition of given temperature and vacuum, it is a ratio of the mass of collected volatile condensable material on surface by given temperature and time to the initial sampling mass. It is usually expressed in percentage.

3.6

total mass loss

TML

for sampling containing volatile condensable material under the condition of given temperature and vacuum, it is a ratio of the total loss mass in given time to the initial sampling mass. It is usually expressed in percentage.

3.7

water vapor regained

WVR

after TML and CVCM tests, samples are exposed again under the given temperature and vacuum. In the given time, the mass of vapor regained by material sampling can be obtained by calculating the mass variation in material sampling. It is usually expressed in percentage.

3.8

recovered mass loss

RML

the total mass loss of material sampling after the regained water vapor has been subtracted (RML=TML-WVR). It is usually expressed in percentage.

3.9

cleanliness level

based on the detection criterion, it is a level divided by the maximum allowable contaminant amount according to the contaminant size, quantity and distribution per unit area or volume in specification.

Note: According to the provisions in GB 50073-2001, the cleanliness level of suspended particles in the air of cleanroom and area is shown from high to low in turn as follows: Level 1, Level 2, Level 3, Level 4, Level 5, Level 6, Level 7, Level 8 and Level 9.

3.10

obscuration factor

a ratio of the surface area precipitated or covered by particle substance to the total area.

3.11

contaminant sensitive part or surface

the part or surface that will affect product performances or service lifetime if contaminated, including solar array, thermal control surface (multilayer, OSR sheet and so on), optical or radiation surface with high cleanliness requirements, moving surface of moving mechanism with high accuracy, sliding contact surface contacts, connectors with high conductivity specifications.

3.12

contaminant sensitivity level

the classification of contamination sensitivity level can be determined according to the impact of contaminant sensitive part or surface carried by satellite on its mission objective. It is divided in turn from low to high as follows: low contamination sensitivity, intermediate contamination sensitivity and high contamination sensitivity.

3.13

contamination control

all measures, organizing and coordinating activities for the assurance of the product cleanliness.

4 General requirements

4.1 General

4.1.1 Satellite contamination control is a system engineering, which runs through the overall process of design, manufacture, test, launching preparation and orbit operation of satellite and its products. The core contents are as follows:

a) Contamination control design;

b) Contamination detection and control in the whole process of development;

c) Contamination treatment in the ground phase;

d) Contamination treatment in orbiting phase.

4.1.2 The integrated contamination control plan shall be included into the system design scheme. The contamination control shall be designed from the top level, and started from the concept design.

4.1.3 The key to satellite contamination control is to strictly control the selection of material on satellite, carry out shielding and protection of the contaminant sensitive parts, clean material and parts properly, carry out baking and degassing treatment, implement a comprehensive contamination control of contaminant sensitive products such as sealing device of propulsion system, thermal control multilayer insulation assemblies, optical instruments, moving parts and other contaminant sensitive products to ensure the contamination be acceptable.

4.2 Selection for material on satellite

4.2.1 According to the contamination sensitivity level of satellite, select material that can meet the requirements for satellite operation.

4.2.2 In selection of satellite material, the following factors shall be taken into account:

a) The outgassing rate of material and its characteristics of variation with time, temperature and pressure (for example, material with low outgassing rate is generally selected for satellite products, and pure mercury, cadmium, zinc and other volatile material are restricted for use);

b) Orbit space environment effects (including UV-radiation, cosmic dust and particulate contaminants, atomic oxygen, electromagnetic radiation, and particle radiation, etc) on material;

c) Geometrical distribution of outgassing material or its components relative to contaminant sensitive piece or sensitive surface (for example, the vacuum outgassing channel of non-metallic material parts or components shall be away from any contaminant sensitive surface as far as possible).

4.2.3 Material on satellite shall be selected from the recommended list. Non-recommended material shall be analyzed and verified before selection. Whether a material is selected or not shall be determined according to the practical application of the specific part and system. The specific principles are as follows:

a) For material not in the view of optical or contaminant sensitive part, it can only be used on satellite when its outgassing performance parameters meet the following requirements. The outgassing performance parameters are tested and obtained according to the test methods specified in ASTM/E 595-1993;

1) General requirements: TML≤1%, CVCM≤0.1%;

2) When the exposed area of material is no more than 13 cm^2 and the material meets the optical or other performance requirements, its outgassing performance parameters specifications can be less stringent to as TML≤3% and CVCM≤1%.

b) For material in the view of optical or contaminant sensitive part, it can only be used on satellite when its outgassing performance parameters meet the following requirements. The outgassing performance parameters can be tested and obtained according to the test methods specified in ASTM/E 595-1993: RML≤0.1%, CVCM≤0.01%.

Note 1: In the above item b), the requirements for material outgassing parameter are more stringent. For most material, it is generally difficult to meet such high specification in the first round of tests according to the regulations in ASTM/E595-1993. In that case it may be obtained in the second round of tests for the material to confirm its outgassing performance parameters.

Note 2: The above mentioned requirement of material outgassing performance parameters in a) and b) can only be a discriminating standard for sieving and comparison in material selection but be not an absolute criteria. It is not guaranteed that the material meeting the above regulations and requirements will not cause any contamination.

4.2.4 For non-recommended material of which the outgassing performance parameter does not meet requirements in 4.2.3, if it must be used on satellite, the following protective measures shall be taken:

a) Minimize the amount of the material as much as possible;
b) Make the material far away from the contaminant sensitive part/surface;
c) Take shielding and isolation measures for the material;
d) Avoid critical contamination caused by outgassing substance to the adjacent parts (for example, critical contamination caused by “water vapor” on infrared detecting element);
e) To perform a strict vacuum baking and degassing procedure.

4.2.5 For non-recommended material of which the outgassing performance parameter meets requirements described in 4.2.3, if it is to be used on satellite, it is necessary to estimate the contamination accumulating effect according to the relative position of the material and sensitive surface, and relevant preventive measures should be taken on this basis (see 4.2.4) to ensure the material vacuum evaporation performance can meet the contamination control requirements.

4.3 Shielding and protection

For contaminant sensitive component, the following shielding and protection measures shall be taken:

a) Mount additional baffles if necessary at the pathway between contamination source and the important surface or sensitive component;
b) Supply gas-filling protective devices for the contaminant sensitive equipment or devices which are located in non-controlled external environment, and maintain the internal atmospheric pressure to be 5 Pa higher than the local atmospheric pressure. Internal gas can be dry clean nitrogen or other inert gases with low condensation point;
c) For humidity sensitive equipment, local heating measures shall be taken in addition to the measures described in b) so that the equipment temperature is no less than 10℃ relative to the local dew point temperature;
d) The exposure time of product in contamination environment shall be restricted according to the product cleanliness requirements or the cleaning possibility.

4.4 Cleaning

4.4.1 The purpose of cleaning is to prevent contaminants from depositing on contaminant sensitive equipment.

4.4.2 Once material and components are selected and the process or manufacture technology is determined, an appropriate cleaning procedure shall be selected to ensure the contamination control of final product meeting the specified requirements.

4.4.3 The selection of cleaning method depends on the type of contaminants to be removed and the physical or chemical properties of the object to be cleaned. The cleaning procedures shall be verified by testing representative samples, or have been verified in previous or similar projects.

4.4.4 For the part which cannot be cleaned, relevant contamination prevention and control measures

shall be taken for all stages that may cause contamination.

4.4.5 For part suitable to be cleaned before the manufacturing process or process treatment (such as bonding, painting, vacuum coating and welding), its cleaning procedures shall be specified in the process specifications.

4.4.6 The auxiliary devices for cleaning shall not cause additional contamination to the part to be cleaned, and its basic selection principles are shown as follows:

a) Auxiliaries (such as wipe cotton, paper, cloth, brush and plastic foam) shall leave no extras;

b) The content of organic contaminant in material for cleaning and wiping ultraclean surfaces shall be no more than $2.0\times10^{-8}g/cm^2$;

c) The damage (scratch) to the cleaned surface shall be controlled in minimum.

4.5 Baking

4.5.1 The main purpose of baking material or parts is to remove the residual contents of diluents, curing agent, solvent and other volatile material added in the curing molding and bonding process from organic material and their structures. In order to improve the baking and degassing efficiency, it is recommended to carry out the baking in vacuum.

4.5.2 Baking shall be applied to all material and parts that can be heated, especially the following:

a) Multilayer insulation assemblies;

b) Carbon and glass fiber parts;

c) Bonding, coating or canned material;

d) Various components which contain non-metallic material.

4.5.3 In the baking process, the following parameters shall be monitored:

a) Vacuum degree: atmospheric pressure less than 10^{-2}Pa;

b) Temperature: depending on outgassing material and cleaning effect.

1) Generally the baking temperature for material shall not be lower than 60℃;

2) The baking temperature for component and product shall be controlled according to the following principles:

— Generally the lowest baking temperature for all parts shall not be lower than 45℃;

— The highest temperature for components which contain non-metal material shall be no higher than 65℃ (the highest temperature for the substrate panel of solar array can be up to 85℃);

— Generally the highest temperature for metal components shall be no higher than 120℃.

c) Duration: 60h~200h (generally, the lower the temperature, the longer the duration);

d) The outgassing rate of material or component.

4.6 Contamination control of special product

4.6.1 Sealing equipment and instruments in propulsion system

More strict contamination control requirements are often applied to storage tank, pipelines, valves, thruster, and other sealing equipment and instruments containing condensable gas components in propulsion system. The contamination control measures shall include the following contents:

a) Analyze the composition of particulate and contaminating gas, especially physically and chemically analyze the volatile condensable matter (VCM) and its contamination influence on important surface;
b) Measure and calculate the variation of source contamination gas pressure with time and temperature;
c) Measure the size of vent hole and the space distribution of jet plume, and take appropriate isolation protection measures according to the specific circumstance;
d) Calculate or measure the cumulative contamination amount on important surface, and take appropriate isolation protection measures according to the specific circumstance ;
e) Determine the leakage rate of sealing system according to the contamination effect of the contamination source, cumulative contamination amount, and allowable contamination degree.

4.6.2 Thermal control multilayer insulation assemblies

4.6.2.1 Multilayer insulation assemblies used on satellite shall be equipped with venting holes. The total area of venting holes shall account for 0.5%~0.6% of that of the multilayer insulation assemblies.

4.6.2.2 For radiation cooler used for deep cryogenic optical detection elements (such as HgCdTe device), the total area of venting holes shall account for 0.9%~1% of that of the multilayer insulation assemblies in designing and allocating venting holes on the multilayer insulation assemblies and relevant processes shall be taken as much as possible to ensure its edge parts being loose when making the multilayer insulation assemblies.

4.6.2.3 All multilayer insulation assemblies shall be protected in a sealed container filled with high purity nitrogen before being assembled on satellite.

4.6.2.4 Before launching (before turning off the air conditioning system in satellite fairing), the humidity inside the fairing shall be controlled a bit lower in advance if possible (the recommended relative humidity control range is 30%~45%) to avoid the too much water hold by thermal control multilayer insulation assemblies contaminating the relevant onboard instruments after launching.

4.6.2.5 In the initial stage of injection, the onboard heaters shall be turned on to heat up and bake the satellite and the multilayer insulation assemblies for degassing.

4.6.3 Optical instruments

4.6.3.1 Selected material shall meet the requirements in 4.2.

4.6.3.2 In instrument structure design, insulation and shielding designs (for example, design a contamination protection cover) shall be adopted to reduce the amount of contaminants that directly reaching the surface of optical element, and make blowing direction of volatiles to be in opposite

direction to that of satellite flying.

4.6.3.3 In instrument thermal design, unbalanced temperature design can be used if possible, so that the condensable substance will be condensed on non-optical surface with lower temperature to avoid condensation effect on optical surface.

4.6.3.4 In addition to the above mentioned measures, for contaminant sensitive instrument parts, the following shall be taken into account:

a) Except the period of thermal vacuum test, the radion cooler and other contaminant sensitive parts shall be protected by high purity nitrogen till launch. Thermal vacuum test shall be carried out in oil-free vacuum system. On the premise of not affecting the whole satellite thermal vacuum test the prototype can be used instead of flight model of the radion cooler and other contaminant sensitive parts for the thermal vacuum test on satellite;

b) Before launching (before turning off the air conditioning system in satellite fairing), the effect of external environment condition on satellite shall be considered in case of the air conditioner is turned off. And appropriate matching control of temperature, humidity and other environment parameters in satellite fairing shall be taken in advance with allowable condition to reserve a sufficient safety margin according to the real external environment conditions;

c) A heating and decontamination device shall be designed and in the initial stage of satellite in orbit, the optical instrument can only be turned on after heating and decontamination according to the procedure requirements.

4.6.3.5 In case pyrotechnics is installed around the instrument, the following measures shall be taken:

a) Prioritize non-contamination pyrotechnics;

b) After rigorous analysis and demonstration, determine the relative position of pyrotechnics to the instrument sensitivity parts;

c) Take rigorous sealing designs for pyrotechnic devices.

4.6.3.6 In each stage of instrument assembly, commissioning, testing, joint test, storage, transportation and pre-launching preparation, ensure temperature, humidity, cleanliness and other environmental conditions are in an effective control state. The general requirements are shown as follows:

a) Temperature: 20℃±5℃;

b) Humidity: 30%~45%;

c) Cleanliness: better than Level 8 specified in GB 50073-2001 when contamination protection hood is covered; better than Level 7 specified in GB 50073-2001 when the contamination protection hood is open.

4.6.4 Moving parts

4.6.4.1 Selected material shall meet the requirements in 4.2.

4.6.4.2 Before applying lubricating material, carry out surface cleaning (surface cleaning shall not

degrade lubrication), and facilitating lubricant bonding or being wet on the surface of substrate.

4.6.4.3 A whole seal or labyrinth sealing structure shall be adopted for moving parts with oil lubrication and necessary measures shall be taken (for example, applying anti-creeping fluorine coating on metal surface at component bearing seal) to prevent lubricating oil from creeping on metal surface and causing any contamination.

4.6.4.4 For any non-sealed moving parts after lubrication treatment, test and performance testing shall be carried out in vacuum environment or under the protection of inert gas.

4.7 Quality management of contamination control

A special contamination control technology group shall be established，responsible for ensuring the verifiability, data integrity and continuity of contamination control activity, and ensuring that products meet the design principles and the requirements for relevant technical specifications.

5 Requirements for contamination control in each phase of satellite development

5.1 Feasibility demonstration phase and initial phase of concept design

5.1.1 Analyze the effect of contaminant sensitive parts or material used by satellite on mission goal, and determine the contamination sensitivity level of satellite.

5.1.2 For satellite with high contamination sensitivity, such as optical remote sensing satellite installed with scanning radiometer, infrared spectrometer, spectral imager and other optical devices, the contamination control work shall be included in the project work plan, and contamination control items shall be established.

5.1.3 For satellite with medium and low contamination sensitivity, such as microwave remote sensing satellites and communication satellites, whether the contamination control is included in the project work plan shall be determined according to specific situations. Contamination control items shall also be established in this phase.

5.2 Design phase

5.2.1 Determine the key contaminant sensitive subsystem (or equipment) and the key subsystem (or equipment) with potential contamination source, summarize and work out the list of contaminant sensitive parts and contaminant sensitive surfaces.

5.2.2 Specify the material selection requirements and the usage approval procedure for material outside the list.

5.2.3 Analyze the work requirements of satellite, possible contamination in each phase of test, launch and flight, and the degree of performance deteriation caused by contamination, and thereafter, assign and regulate the allowable contamination level for each onboard instrument (especially for those contaminant sensitive part or surface).

5.2.4 In design (or technological) review, the following contents of contamination control for the key

contaminant sensitive subsystem (or equipment) shall be included:

a) Contamination control items and work plan;
b) Contamination source analysis;
c) List of contaminant sensitive parts (or surfaces), contamination effect and criticality analysis, contamination control measures and so on;
d) Material selection and control;
e) Cleaning probability of material and mechanical parts;
f) Component and characteristic analysis of gas released from sealed container, thruster, pyrotechnics, etc; monitoring and analysis on pressure and temperature; vent path design and effect analysis, etc.

5.3 Manufacturing phase

5.3.1 When implementing relevant operations such as welding, gluing, painting, grinding, etc. on satellite and its onboard instruments, which may possibly generate contamination, necessary contamination protection measures shall be taken and various residues (flux, metal scrap, slice, fiber and so on) removed from products timely after completing the above operations.

5.3.2 The operation table shall be clean, oil, solder, scrap and other wastes removed timely.

5.3.3 After silver plated part is processed, it shall be packed with capacitor paper and placed into a dry container to prevent any oxidation or sulfide blackening.

5.3.4 After liquid and gas pipelines being cut to remove burrs, specified clean-up operations shall be carried out and the ends of pipeline shall be sealed. After installation and before operation, if any contamination in pipeline is found during inspection, measures shall be taken to remove any contamination.

5.3.5 During the production and operation process, protective cover or hook shall be installed on components (assemblies) that is susceptible to be contaminated. Except for special operations, the protective cover or hook shall be maintained always at the specified protection position.

5.3.6 Products (parts, components and assemblies) produced in non-clean area or under non-clean conditions are the objects of cleaning process. They shall not be packaged and delivered until reaching the requirements of specified cleanliness level.

5.3.7 Products (parts, components or assemblies) which can be cleaned after manufacturing shall be cleaned according to appropriate and effective procedures to ensure that they can meet the requirements of specified cleanliness level. For any product (part, component or assembly) which cannot be cleaned after manufacturing, its manufacturing and processing area shall meet the requirements of specified cleanliness level.

5.3.8 After completing the final processing, contaminations shall be removed from parts (components) timely. Oil sealed parts shall be cleaned clearly before sealing.

5.4 Assembly and integration phase

5.4.1 Contamination control for cleanroom

5.4.1.1 The control requirements of air cleanliness of cleanroom (concentration of airborne suspended particulate substance), concentration of contaminated gas, amount of particulate landed on surface or shadowing factor, and organic contamination quantity shall be proposed by the research and development unit according to required product temperature, humidity, gas pressure, wind speed, noise, vibration and other conditions.

5.4.1.2 For other requirements, refer to relevant provisions in GB 50073-2001.

5.4.2 Contamination control in operation process

5.4.2.1 A cleanliness control process shall be prepared for any key assembly process with contamination control requirement.

5.4.2.2 A special procedure shall be set up for assembling key parts.

5.4.2.3 Key and sensitive components can only be taken out of container in necessary operation process and shall be put back into its special container after use.

5.4.2.4 Components (assemblies) not to be assembled temporarily shall be covered with dustproof cloth to prevent dust from entering the products.

5.4.2.5 Before installing and assembling components (assemblies), the production tools, operation test bench, ladder, special test equipment and others shall be checked to ensure their cleanliness.

5.4.2.6 Check whether protection devices (such as dust-proof cover, temporary seal, mat, etc.) are installed correctly. For any case that the protective device fell off or lost, the reason should be investigated. After removing contaminations, the protective device shall be installed again.

5.4.2.7 when some parts (components or assemblies) are required to be removed before assembling , ensure the process blocking plug, scutcheon, label, assembling devices (such as alligator clip) and other auxiliary material being cleaned to prevent any contamination.

5.4.2.8 In the assembly process, minimize the assembly and disassembly times. Aluminum parts and other soft metal parts are not allowed any repeated assembly and disassembly, to prevent aluminum or other metal powder falling into the product.

5.4.2.9 In the process of assembly, any remachining processing is not allowed. If it is necessary to do so, special technological measures and processing site shall be specified to prevent any contamination.

5.4.2.10 Plugs and sockets of high, intermediate and low frequency shall be cleaned clearly before installing. After welding, clean the flux thoroughly. When welding any low frequency socket, incline the tools to prevent flux from flowing into pin and socket and affecting electric contact. Plugs shall be equipped with protective cover to prevent dust from entering.

5.4.2.11 For any part that cannot be checked any more after being assembled, a double post system shall be implemented and inspection personnel be at the working site to confirm the cleanness condition jointly before carrying out assembly.

5.4.2.12 During the period of assembly, any operation (such as drilling, cutting, screw tightening, etc.), possibly generating particulate contaminations shall be reduced; any visible particulate or other contamination accumulating on parts is not allowed. Once found, they shall be removed immediately (measures to be taken include vacuum baking degassing, vacuum cleaner suction, dry cleaning, solvent cleaning, etc.).

5.4.2.13 All fastening elements including rivet, screw, nut, washer and related components used in the assembly process shall be free of any oil, and meet the outgassing requirements.

5.4.2.14 For material and component that can be heated (especially for material and component of high contaminant sensitive product), arrange a vacuum baking process appropriately to carry out degassing treatment. For specific requirements, see 4.5.

5.4.2.15 Contamination prevention and control measures and inspection requirements shall be drawn out for products returning to factory for repair.

5.5 Measuring phase

5.5.1 In the measuring process, either indoor operators walking nearby or handling, pulling equipment, tools in the test room is restricted or prohibited.

5.5.2 In the measuring process, the environmental conditions such as temperature, humidity and gas pressure shall be monitored continuously. Suspended particulate and organic contamination shall be monitored regularly according to the requirements for product cleanliness. If the changed value of environmental condition exceeds the specified requirements, terminate the test till it is restored and can be controlled again.

5.5.3 For product being particularly sensitive to contamination, be sure to take various contingency measures for air filter, dehumidification device and temperature control device in case of failure and cutting off the power in emergency situations.

5.5.4 For optical components, optical surface working under ultra-low temperature conditions and other equipment with special requirements, carry out local low-positive-pressure gas purging protection with dry and clean nitrogen or high purity nitrogen to maintain local environments in a protective conditions of nitrogen with relatively ultra-low humidity, to avoid vapor condensed in those position, occurring condensed water, frost, ice and metal corrosion on key parts hence, resulting in product performance degradation or functional failure.

5.5.5 In the measuring process, the contaminant gas, solvent residue, particulate substance shall be discharged or removed timely. It is prohibited to drive contaminant to other cleaning products and testing devices.

5.5.6 After completing the product assembly and the assembly test, carry out complete or local cleaning again according to the requirements for product performance, quality assurance requirements, product bearing contamination degree and important surface accessibility before product being packed, stored or

to be transported to the launch site.

5.5.7 Satellites shall be tested in a controlled environment at the launch site. The air cleanliness in closed room and fairing of satellite test workshop and launching tower frame shall be better than Level 8 specified in GB 50073-2001. The organic contamination amount in 24 hours shall be no more than $1\times10^{-6}g/cm^2$. Temperature, humidity and others shall be controlled correspondingly according to product performance requirements.

5.6 Testing phase

5.6.1 General requirements

For the contamination control requirements during the general testing process, see 5.5.1.

5.6.2 Contamination control of thermal vacuum test

5.6.2.1 Contamination control items before testing include:

a) Establishment, control and acceptance for environmental conditions of vacuum chamber (temperature, humidity, pressure, cleanliness and organic contaminant);

b) Strictly control material into the vacuum chamber. any material that does not meet the requirements in 4.2.3 is not allowed in principle;

c) For any material with high outgassing rate (such as multilayer insulation assemblies, carbon and glass fiber element, bonding, coating, canned material, etc.) that needed to be put into the chamber, shall pass through vacuum baking treatment;

d) After the vacuum chamber operates continuously for 24 hours in no-load condition, the contamination amount of organic substance shall be no more than $1\times10^{-7}g/cm^2$. The no-load test shall be able to represent the actual test (including test equipment, cable, etc.) including a pumping and re-pressurization process.

5.6.2.2 The contamination control items in testing include:

a) Carry out test pre-treating (such as vacuum desorption, degassing, etc.), to reduce various attachments and self-generated contaminants in satellite and test equipment;

b) Carry out formal tests according to the pre-determined working condition and procedures. In testing, necessary contamination monitoring methods shall be provided. For example, carry out overall contamination amount monitoring with quartz crystal micro scale, quadrupole mass spectrometer and other instruments;

c) When necessary, mount and suspend test pieces to collect any deposited contaminants in test. Specific requirements are shown as follows:

   1) Generally, test pieces are aluminum-coated lenses or other glass pieces;

   2) Before testing, wipe test pieces, detect their emission rate with visual inspection and spectrometer, and confirm test pieces being clean and usable;

   3) Test pieces shall be arranged and placed according to the following principle: for test piece being arranged for contaminant sensitive product, its contamination collection surface shall

be as close as possible and be parallel to the contaminant sensitive surface of product. For test piece being arranged for possible contamination source onto satellite body, its contamination collection surface shall face to the contamination source;

4) At the end of test, first detect its emission rate with visual inspection and then spectrometer (compare with detection data before testing). If necessary, determine the standard contamination component to identify and control the contamination source by spectrometry or infrared spectroscopy and other surface analysis methods.

d) After completing each scheduled test of different working condition, control the operating procedures strictly to carry out temperature returning and re-pressurization (for example, during the process of heat sink and temperature rise, pay attention to maintaining the external surface temperature of satellite to be 10℃~15℃ higher than that of the heat sink. Contamination cooling plate still keeps a relatively lower temperature as compared as that of the heat sink. During the air filling and re-pressurization process and before filling air, confirm that the dew point temperature of air is less than the temperature of satellite surface and the heat sink).

5.6.2.3 Contamination control after testing shall include:

a) Carry out contamination detection of satellite, and remove various contaminations timely;

b) Take contamination protection measures for high contaminant sensitive products (such as filling high purity nitrogen for protection).

5.6.3 Moisture control of thermal cycle test under normal pressure

5.6.3.1 For product with high contamination sensitivity of water and vapor (such as radiation cooler and moving part with solid lubricant), avoid this kind of test as far as possible.

5.6.3.2 When satellite product is in thermal cycle tests under normal pressure, pay attention to the following situations that can cause product being damped easily.

a) Air is in a high temperature and humidity state in test chamber (for example, the temperature is not lower than 30 ℃, and the relative humidity is no less than 60 %);

b) The humidity of air in test chamber is from low to high, and the temperature is also from low to high;

c) The temperature of air in test chamber is changing sharply from low to high.

5.6.3.3 To avoid satellite being damped in thermal cycle test under normal pressure, generally the following measures are taken:

a) Add thermal insulation material at the cable hole and other position with poor sealing and insulation performances;

b) Adjust the air circulation device and the placement mode of the test specimen to ensure flowing uniformity and comprehensiveness of circulating air in test chamber;

c) In the test, it is appropriate to take high temperature pre-baking and other measures to eliminate

water vapor from the test chamber and internal part of the test specimen. Then, begin the formal test. Before the end of test, it is suitable to set the final half-a-circle as the thermal circling condition so as to reduce the water vapor residue in test chamber and the test specimen;

d) In the test, fill with dry air or nitrogen with certain pressure continuously into test chamber, so as to prevent external water vapor from entering into test chamber.

5.7 Storage phase and transportation process

5.7.1 Storage phase

In the storage phase, the contamination protection measures and requirements for satellite mainly include:

a) Carry out cleaning treatment of satellite before packaging and storing;
b) The container to be used for cleaning the parts shall keep the same cleanliness level specified for the product;
c) During the planned storage period, storage area shall provide with sufficient protections for packages or products;
d) Container to store or transport contaminant sensitive parts shall be internally cleaned thoroughly before putting products into it;
e) When storing contaminant sensitive parts, the contaminant sensitive surface shall be placed face down to minimize the particulate deposition contamination as far as possible;
f) The container selected shall be easy for surface cleaning and inspection, and avoid any dust accumulation in dead corner;
g) Small cleaned parts shall be kept in double-layer sealing bag during the storage or transportation process outside the controlled cleaning area;
h) Bags for loading contaminant sensitive parts or sensitive surface shall be filled with dry high-purity nitrogen and then sealed;
i) The electrostatic sensitive parts shall be packed and stored in bags with metal-coated thin film;
j) Avoid using PVC for packing and storing optical devices.

5.7.2 Transportation process

In the process of transportation the contamination measures and requirements for satellite mainly include:

a) In the process of transportation, especially for the key satellite products, precautious measures shall be taken. The manufacturer shall provide transportation containers which meet the design requirements to ensure the transportation environment meeting the requirements of cleanliness level;
b) For any high contaminant sensitive satellite or component, special containers shall be designed and produced. During handling, the container or the equipment in it shall not generate any particulate shedding or gas and liquid leakage.

c) Containers and auxiliary equipment shall be equipped with necessary environment control, monitoring and warning devices to ensure there will not be any contamination or corrosion on satellite product or any performance change in the transportation process;

d) For any water vapor sensitive satellite product, generally there shall be internal temperature and humidity monitoring devices in the special packaging container. Their reading display (or indicator) shall be set at a position to facilitate the observation in the storage or transportation process.

5.8 Launching test phase

5.8.1 Establish perfect responsibility system of launching test contamination control.

5.8.2 Develop all-round technical requirements for launching test contamination control. The items mainly include:

a) Develop the contamination control technical procedures for satellite launching test;

b) Develop contamination technical requirements for transporting satellites to the launch site(transport process and unloading of satellite products);

c) Develop technical requirements for satellite contamination control in technical area;

d) Develop technical requirements for satellite contamination control when it is being transported from technical area to launch area;

e) Develop technical requirements for satellite contamination control in launch area;

f) Develop the fault counter plan in contamination control of satellite launching test.

5.8.3 Co-organize and negotiate with launching site team and launch vehicle team to take various contamination control measures for launching tests, and carry out joint supervision and inspection. The items mainly include:

a) Determination of environmental conditions and requirements (including temperature, humidity, cleanliness, nitrogen source quality and quantity, etc.) for satellite testing station in launch site (technical area and launch area);

b) Establishment and acceptance approval of environmental conditions (including temperature, humidity, cleanliness, nitrogen source quality and quantity and so on) for satellite testing station in launch site (technical area and launch area);

c) Establishment and acceptance approval of environmental conditions for fairing (including temperature, humidity, cleanliness, non-volatile residue, air quantity, wind speed, etc.);

d) Monitoring and control of environmental conditions (including temperature, humidity, cleanliness, nitrogen source quality and quantity, etc.) for satellite testing station and fairing in launch site (technical area and launch area);

e) Develop perfect satellite contamination control scheme and details for the effect of external environment condition on satellite after the air conditioning system of satellite fairing has been

turned off before launch.

5.9 Orbiting phase

In orbiting phase, contamination measures and requirements for satellite products mainly include:

a) Contamination treatment in the early stage of injection:
   1) Set reasonable operating procedures for high contaminant sensitive devices (for example, contamination removal and heating procedures for fairing separation of radiant cooler);
   2) Degassing of satellite system (start the heater on satellite generally to carry out heating, baking and degassing for satellite system);
   3) Determine the startup time of high contaminant sensitive remote sensing devices.
b) Contamination treatment in the phase of long term orbit operation:
   1) On-orbit contamination monitoring and analysis on contaminant sensitive parts or surface on satellite;
   2) Treatment to the contaminated parts on satellite (generally through heating and baking).