General

CONTAMINATION CONTROL STANDARD

This standard is a revision of the JAXA program management requirements document JMR-010 provisional version (established in 2004) based on the former NASDA-STD-26, while maintaining consistency with ISO-15388.

Mar 31, 2020

Japan Aerospace Exploration Agency

This is an English translation of JMR-010A, “CONTAMINATION CONTROL STANDARD”, and does not constitute itself.
Whenever this document conflicts with the original document in Japanese, the original document takes precedence.

Published by
Japan Aerospace Exploration Agency
Safety and Mission Assurance Department
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Contents

1 GENERAL

1.1 Purpose

This contamination control standard (hereinafter referred to as "this Standard") specifies the requirements for contamination control applied to the development, launch and orbital operation of the spacecraft to prevent the deterioration of spacecraft performance due to contamination and to achieve the purpose of the mission. And this Standard provides guidelines for setting up a contamination control program.

The purpose of contamination control is to prevent the deterioration of the performance of the space system due to particle contamination and molecular contamination (including biocontamination), and to ensure that the mission objectives are achieved.

1.2 Scope

1.2.1 Scope

When this Standard is called into technical specification, procurement specification, etc., it applies to the Japan Aerospace Exploration Agency (hereinafter referred to as "JAXA") and/or the contractor to the following extent.

This Standard is applied when contamination control is deemed necessary in each phase of the project such as design, manufacturing, assembly, integration, testing, transportation, storage for spacecraft system, components and parts including pre-launch work, launch, in-orbit operation and post-mission work.

However, the following items are not covered by this Standard.

a. Measures against radioactive contamination

b. Measures to prevent debris (Specified by JMR-003 Space Debris Mitigation Standard)

c. Planetary protection (Specified by JMR-014 Planetary Protection Program Standard (in Japanese))

1.2.2 Tailoring

(1) The requirements of this Standard can be tailored for each project according to the purpose, function, importance, scale, etc. of the spacecraft.

(2) When there are any items that are difficult to comply with among the requirements of this Standard for existing facilities and ground support equipments used for ground works such as manufacturing, assembly, and testing, the requirements can be tailored in consultation with the requester of this Standard application after clarifying the reason.

2 RELATED DOCUMENTS

2.1 Applicable documents

The following documents shall be part of this Standard within the scope specified in this Standard, and the latest version at the time of the contract shall be applied unless otherwise specified.

In case of a conflict between this Standard and the following documents, this Standard shall take precedence.

(1) JMR-004 Reliability Program Standard
(2) JMR-005 Quality Assurance Program Standard
(3) JMR-013 Quality Assurance Program Standard (Basic Requirements: JIS Q 9100)
(4) ISO 14624-3 Space systems -Material Flammability, odor, offgassing and compatibility‐Part 3: Test Method for Determination of Offgassed Products from Materials and Assembled Articles
(5) ISO 14644-1 Cleanrooms and associated controlled environments - Part 1: Classification of air cleanliness
(6) ISO 15859-1 Space systems - Fluid characteristics Part 1: Oxygen
(7) ISO 15859-2 Space systems - Fluid characteristics Part 2: Hydrogen propellant
(8) ISO 15859-3 Space systems - Fluid characteristics Part 3: Nitrogen
(9) ISO 15859-4 Space systems - Fluid characteristics Part 4: Helium
(10) ISO 15859-5 Space systems - Fluid characteristics Part 5: Nitrogen tetroxide propellant
(11) ISO 15859-6 Space systems - Fluid characteristics Part 6: Monomethyl hydrazine propellant
(12) ISO 15859-7 Space systems - Fluid characteristics Part 7: Hydrazine propellant
(13) ISO 15859-8 Space systems - Fluid characteristics Part 8: Kerosene propellant
(14) ISO 15859-9 Space systems - Fluid characteristics Part 9: Argon
(15) ISO 15859-10 Space systems - Fluid characteristics Part 10: Water
(16) ISO 15859-11 Space systems - Fluid characteristics Part 11: Ammonia
(17) ISO 15859-12 Space systems - Fluid characteristics Part 12: Carbon dioxide
(18) ISO 15859-13 Space systems - Fluid characteristics Part 13: Breathing air
(19) ISO 14952-2 Space systems - Surface cleanliness of fluid systems- Part 2: Cleanliness levels
(20) MIL-STD-889 Dissimilar Metals
(21) ASTM E 595 Standard Test Methods for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
(22) ASTM E 1559 Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials

2.2 Referenced documents

The following documents are for reference only to supplement the content of this Standard.

(1) JMR-003 Space Debris Mitigation Standard
(2) N/A
(3) SR70-04 H-IIA Rocket Range Launch Maintenance Work Request Form (in Japanese)
(4) ISO 14625 Space systems - Ground support equipment for use at launch, landing, or retrieval sites - General requirements.
(5) ISO 14644-2 Cleanrooms and associated controlled environments - Part 2: Specifications for testing and monitoring to prove continued compliance with ISO14644-1.
(6) ISO 14644-4 Cleanrooms and associated controlled environments - Part 4: Design, construction and start up of cleanroom facilities
(7) ISO 14644-5 Cleanrooms and associated controlled environments - Part 5: Design, Operations
(8) ISO 14698-1 Cleanrooms and associated controlled environments – Cleanroom technology - Biocontamination control: General principles
(9) ISO 14698-2 Cleanrooms and associated controlled environments – Cleanroom technology - Biocontamination control: Evaluation and interpretation of biocontamination data
(10) ISO 14698-3 Cleanrooms and associated controlled environments - Cleanroom technology – Biocontamination control: Methodology for measuring the efficiency of processes of cleaning and (or) disinfection of inert surface bearing biocontaminated wet soiling or biofilms
(11) JSC SN-C-0005 Contamination Control Requirements for the Space Shuttle Program
(12) NASA-CR-4740 Contamination Control Engineering Design Guidelines for the Aerospace Community
(13) SSP 30426 Space Station External Contamination Control Requirements
(14) JMR-014 Planetary Protection Program Standard (in Japanese)

2.3 Referenced data base

The database below is for reference only to supplement the content of this Standard.
(1) Material database http://matdb.jaxa.jp/main_j.html

3 DEFINITION OF TERMS

3.1 Definition of terms

(1) Air quality

Concentration of suspended particles in the air as defined by ISO 14644-1 (or FED-STD-209). Refer to ISO 14644-1.

(2) Baking

The act of raising the temperature of the hardware to accelerate the outgassing rate with the intention of reducing the content of molecular contaminants in the hardware. Baking is usually done in a vacuum environment, but it can also be done in a controlled atmosphere.

(3) Beginning of life (BOL)

Beginning of the operation life (mission life) of the system.

(4) Bioaerosol

Scattering of organisms (ex. growing particles, allergens, toxins, or biological action mixtures of pathogens) in a gas atmosphere. Refer to ISO 14698-1.

(5) Biocontamination

Contamination of materials, devices, solids, surfaces, liquids, gases, or air with live particles (molds, fungi, etc.). Refer to ISO / CD 14698-1.

(6) Classification of airborne particle concentration

The level of particle cleanliness suspended in the air (or the process of clarifying, or the determination of the level) is expressed as the maximum permissible concentration of the estimated particle size (number of particles / m^3). Refer to ISO 14644-1.

(7) Clean area

Areas where spacecraft are manufactured, assembled, tested, etc. are divided as follows. The area other than the "a. conventional industrial area" is called a clean area.

a. Conventional industrial area
b. Managed work area (equivalent to ISO 14644-1 CLASS 9)
c. Normal clean room (equivalent to ISO 14644-1 CLASS 8)
d. Laminar flow clean room (equivalent to ISO 14644-1 CLASS 5, 6, 7)

(8) Cleanliness

The amount of contaminants predicted or measured within a given area or volume, or on a component.

(9) Cleanliness Requirement Specification (CRS)

A document that defines and identifies the spacecraft items and the environmental areas which are sensitive to contamination, the acceptable contamination levels at BOL and at EOL and the applicable contamination environment.

(10) Clean room

A room that is controlled the concentration of particles suspended in the air, constructed by means that minimizes the intrusion, generation, and retention of particles in the room, and controlled temperature, humidity, pressure as required. Refer to ISO 14644-1.

(11) Cleanroom garments

Clothes that are specially designed, made and worn so that personnel working in a clean room do not contaminate the hardware.

(12) Collected volatile condensable material (CVCM)

The mass ratio of the gaseous substance released from the specimen condensed on the collector while the specimen and collector are held at the specified temperature for a certain period of time. For CVCM, the amount of condensate is calculated from the mass difference of the collector plate before and after the test and expressed as a percentage of the initial specimen mass. Refer to ASTM E-595.

(13) Contaminant

Undesirable molecular or particulate material that may deteriorate or affect performance or life.

(14) Contaminate

Act of adhering contaminants.

(15) Contamination

Adhesion or contamination of materials, fluids, or surfaces.

(16) Contamination budget

Allowable level of cleanliness allocated to each hardware in each phase of ground and in-orbit operation.

(17) Contamination and Cleanliness Control Plan（CCCP）

A document that describes how the contamination control program should be run. Described in a separate document or in a comprehensive project plan.

(18) Contamination control program

Organizational activities for contamination control according to this Standard.

(19) Contamination profile

State related to contamination in each phase of ground and orbital operation. The contamination profile includes the cleanliness class of suspended particles, pressure, humidity, temperature, personnel engaged in operation, cleaning activities, facility outline, etc., and forms part of the contamination control plan.

(20) Conventional industrial area

Areas where contamination control is not performed.

(21) Electrostatic discharge (ESD)

Transfer of static charge between objects with different potentials. This occurs when relatively close or due to direct contact.

(22) End of life (EOL)

End of the operation life (mission life) of the system.

(23) Gas cleanliness

The amount of particles and impurities per unit volume of gas. These quantities are expressed in number, mass or volume. Refer to ISO 14951-1 to -13, SR70-04.

(24) Ground Support Equipment (GSE)

Non-flight systems, equipment, or equipment required to assist spacecraft transport, receipt, handling, assembly, inspection, testing, checkout, service, launch and recovery operations at launch, re-entry and recovery sites. Refer to ISO 14625.

(25) Interface control document (ICD)

A document that describes the characteristics that must be managed at the boundaries between systems, subsystems and other equipment.

(26) Laminar flow

A uniform flow of air from the air inlet to the outlet without turbulence that winds up contaminants.

(27) Liquid cleanliness

The amount of particles and impurities per unit volume of liquid. These quantities are expressed in number, mass or volume. Refer to ISO 14951-1 to -13, SR70-04.

(28) Micro-organism

A microscopical individual with a life-supporting function. Organisms, including bacteria, unicellular animals, yeasts, viruses and algae, etc.

(29) Molecular Contamination

A state in which unintended molecules are deposited on the surface. Or a state in which unintended molecules are present in a gas or liquid. Adhesion or contamination of materials, fluids, or surfaces with molecular contaminants. Most of them are generated from outgassing released from equipment in a vacuum, and often originate from adhesives, lubricants, other organic materials and human fat.

(30) Non volatile residue (NVR)

Solid phase or liquid phase remaining after volatilizing the filtered volatile solvent. NVR is usually expressed in terms of mass per unit volume of liquid, but when a volatile solvent-soluble contaminant is removed from a particular region of a solid surface, NVR is expressed in terms of mass per unit area.

(31) Occupancy states of cleanrooms

At-rest: A state where the equipment is installed and can be operated by the method agreed between the JAXA and the contractor, but there are no personnel.

Operational: A state in which it is functioning according to the specified procedure, has a specified number of personnel, and is operating in an agreed manner.

(32) Offgassing

Emission of gas from liquid or solid materials in a pressurized environment. It causes health hazards when a person inhales the released gas component. It is managed from the perspective of interpersonal toxicity.

(33) Outgassing

The release of gas from the material, which usually occurs in vacuum. It causes deterioration of the material that is the release source and pollution due to the released gas component adhering to the sensitive surface. It is managed from the viewpoint of contamination prevention.

(34) Particle

A mass of material that has an observable length, width, and thickness.

(35) Particle concentration (surface)

Number of particles per unit area.

(36) Particle concentration (volume)

Number of particles per unit volume of fluid.

(37) Particle Size

The maximum length of a particle that can be clearly identified on the monitoring surface when observed with a measuring instrument such as an optical microscope or an electron microscope, or a considerable diameter of the particle detected by an automatic measuring instrument. The equivalent diameter is the diameter of the particles that show the same reaction as a matching sphere with known characteristics by a measuring instrument that can measure particles.

(38) Particulate contamination

Adhesion or contamination of materials, fluids, or surfaces with particulate contaminants. It often originates from dust in the air, human hair or small pieces of coating.

(39) Purge

The act of pushing out and removing the fluid (gas or liquid) remaining in the container with another clean fluid. In addition, it can be used for the purpose of preventing the invasion of contaminants from the outside.

(40) Recovered mass loss (RML)

The value obtained by subtracting the adsorbed water from the mass loss ratio of the specimen (RML=TML–WVR). For some spacecraft, RML is defined because water is not a significant contaminant.

(41) Responsible organization

An organization delegated the resources and authority needed to achieve the goals of a contamination control program.

(42) Sensitive hardware

Hardware whose quality may deteriorate due to contamination.

(43) Sensitive surface

The surface of an article or structure that may lead to quality degradation due to contamination.

(44) Significant surface

The surface of hardware that requires the specified cleanliness.

(45) Supplier

When applying this Standard to the JAXA , it is the counterparty to the contract with the department that receives the request within the JAXA. In addition, when applying this Standard to the contractor, they are individuals, companies or business establishments that directly or indirectly supply goods, etc. including the other business divisions within the same company and the cooperating companies.

(46) Surface Cleanliness

Significant surface cleanliness. Particulate contamination is categorized by the size and number of particles per unit area of a significant surface and is defined by the maximum particle size. Molecular contamination is defined by the mass per unit area of a significant surface. Refer to ISO 14952-2.

(47) Total mass loss (TML)

The mass ratio of gaseous substances released from a specimen held for a specified period of time at a specified constant temperature and pressure. TML is calculated from the mass of the specimen weighed before and after the test and is expressed as a percentage of the initial specimen mass. Refer to ASTM E-595.

(48) View factor

In the field of contamination control, the view factor when the polluted object is viewed directly from the contamination source.

(49) Visibly clean (VC)

No surface contamination when inspected with specified light source and incident angle, viewing distance and angle and standard visual equipment or magnifying glass. Refer to ISO 14952-2. (46)

(50) Volatile condensable materials (VCM)

Of the gaseous substances released from a material exposed to vacuum, substances that condense on other materials at temperatures lower than that material.

(51) Water vapor regained (WVR)

Mass ratio of water vapor reabsorbed in the specimen to the initial specimen calculated from the difference between the total mass loss ratio (TML) and collected volatile condensable material (CVCM) test specimen mass and the specimen mass weighed again after exposure to air at a

relative humidity of 50% and 23 ° C for 24 hours. WVR is expressed as a percentage of the initial specimen mass. Refer to ASTM E-595.

3.2 Abbreviation

(1)	ASTM	American Society for Testing and Materials
(2)	CVCM	Collected Volatile Condensable Material
(3)	FMEA	Failure Mode and Effect analysis
(4)	GSE	Ground Support Equipment
(5)	IPA	Iso Propyl Alcohol
(6)	ISO	International Organization for Standardization
(7)	MLI	Multi-Layer Insulation
(8)	NASA	National Aeronautics and Space Administration
(9)	NVR	Non-Volatile Residue
(10)	QCM	Quartz Crystal Microbalance
(11)	TML	Total Mass Loss
(12)	VC	Visibly Clean
(13)	VCM	Volatile Condensable Material
(14)	BOL	Beginning of Life
(15)	EOL	End of Life

4 GENERAL REQUIREMENTS

4.1 Control

4.1.1 Organization

4.1.1.1 Clarification of implementing organization and responsibilities, and implementation

In order to plan and execute a contamination control program, a contamination control organization shall be established at the start of the project according to the configuration and level identified in the project. At the time of establishment, a person in charge of contamination control shall be appointed. The contamination control organization may utilize the existing organization.

In addition, the content of the contamination control program will be decided based on mutual agreement between the requesting party and the receiving party to apply this Standard.

Contamination control organizations shall comply with the requirements of this Standard.

4.1.1.2 Requirement to suppliers

Contamination control requirements for the work shall be established and performed by the supplier. The cleanliness of the product required to the supplier shall be considered to meet the performance requirements of the product.

4.1.2 Cleanliness requirement specification

The hardware that requires contamination control shall be identified and the cleanliness to be achieved shall be defined quantitatively. The identified hardware shall include all items from the component level to the system level. Hardware cleanliness shall be defined at the beginning of life (BOL) and the end of life (EOL) based on feasible requirements. Cleanliness requirement specifications shall be established independently or included in project management documents (development specifications, management plans, design specifications, etc.). The hardware cleanliness requirements for interfaces with systems, subsystems and other equipment shall be clarified early in the program and specified in the interface control document in Section 4.1.4 or an equivalent document.

4.1.3 Contamination control plan

The supplier shall formulate an activity plan for contamination control from design to operation.

Also, the supplier shall allocate contamination budgets in all phases of the project and clarify how to achieve the required cleanliness.

(1) When individually requested, the supplier shall create a contamination control plan that describes how to achieve and maintain the specified cleanliness of the hardware throughout all phases of ground and in-orbit operations. When sensitive hardware is not included, it may be included in the project management document such as the program implementation plan instead of the independent document.

(2) The contamination control plan shall be presented in the preliminary design reviews at the latest and shall be reviewed for conformity with this Standard and technical specifications. In addition, the subsequent maintenance and management shall be carried out appropriately, and the design review of each phase shall be done.

(3) The scope of application and the level of requirements of the contamination control plan shall be determined by the contamination control organization, taking into account the importance of hardware to contamination. In addition, additional work may be required in response to the requirements of this Standard.

(4) The contamination control plan shall include the following.

a. List of applicable documents, etc.
b. Contamination control organization
c. Review method and timing of contamination control activities
d. Record of contamination control activities
e. Procedure for contamination control activities
f. How to do design management activities related to contamination (design review, design / process FMEA, programs related to parts / devices / materials / processes, etc.)
g. Definition of a single failure mode that includes equipment failures and human error that affects cleanliness
h. Contamination budget in all phases of ground and orbital operations
i. Procedures for qualification of parts, devices, materials and processes
j. Procedure of manufacturing process review related to contamination
k. Measurement, monitoring requirements, procedures and methods
l. Procedure for confirming the effectiveness of materials and equipment
m. How to achieve and maintain the required cleanliness
n. Measures when it is predicted that it will be difficult to achieve the required cleanliness
o. Prescriptions in case of deviation from required cleanliness
p. Non-conforming product treatment procedure

q. Personnel education / training and methods
r. Important management items to be reflected in the procedure manual
s. Definition of the risk of mutual contamination between hardware elements

(5) The contamination control plan shall be reviewed by the requester for application of this Standard.

4.1.4 Interface control document

(1) Cleanliness of interfaces with different systems, subsystems and other equipment shall be controlled by the interface control documents or the equivalent documents.
(2) The interface control document may include the following information.
a. Particle, gas, vapor and dust limits between interfaces.
b. Restrictions on particle, gas, vapor and dust in the hardware's field of view to control.
c. Limitation of energy factors (ultraviolet and ionizing radiation, atomic oxygen, etc.) that affect contaminant deposition and reduce performance.

4.1.5 Examination and performance confirmation of contamination control program

In order to prove that the status is recorded, appropriate activities are planned and performed, and achieved as required, the contamination control program shall be reported to the project review board for confirmation of implementation. A comprehensive project management plan, or contamination control plan, shall describe when and how contamination control activities are reviewed. The scope of review by the requester of the application of this Standard shall be determined through consultation.

4.2 Management at design phase

4.2.1 Identification of sensitive hardware

Sensitive hardware that should be adequately protected shall be identified among the contaminants, their sources and the contaminated targets affected by them throughout the entire period from spacecraft manufacturing to the end of the mission.

4.2.2 Identification of process control parameters by process FMEA

By performing FMEA in the manufacturing process, parameters that affect the cleanliness of sensitive hardware shall be identified as process control items.

4.2.3 Properties, impacts and profiles of contaminants

The following for contaminants shall be identified.

(1) Properties of contaminants that can degrade performance due to particle, molecular, or biocontamination throughout all phases of ground and in-orbit operations for sensitive hardware.

(2) Impact of contaminants on sensitive hardware through similar spacecraft and similar operational experience and data obtained in field trials. These should be confirmed in the early phase of the project.

4.2.3.1 Typical contamination source

Typical contamination sources (including the re-emission of condensed contaminants) include the followings.

(1) Contamination source on the ground

a. Molecular contamination

(i) Atmospheric component gas, water vapor

(ii) Gas generated from organic materials (monomers, plastics, adhesive paints, solvents, etc.)

(iii) Steam from test equipment (vacuum pump oil mist, etc.)

(iv) Detergent and masking tape residues

(v) Machine oil and lubricant for moving parts of machines

(vi) Flux at solder joint

(vii) Human body of personnel (cosmetics, sebum, etc.)

(viii) Leakage from pressurized units

(ix) Packing material

b. Particulate contamination

(i) Atmospheric dust, sand, exhaust fumes, micro-organisms

(ii) Human body of personnel (dandruff, red, etc.)

(iii) Chips and burrs on machined surfaces

(iv) Solder droplets, solder balls, wire chips, welding spatter

(v) Powder remaining in the process of removing the oxide film due to defective shield gas during welding

(vi) Foreign matter mixed in when releasing vacuum such as EBW (electron beam welding)

(vii) Coating piece peeled off from the coated surface

(viii) Residual foreign matter due to poor cleaning

(ix) Disperses from packaging materials during transportation

(x) Grains generated in the test equipment

(xi) Grains from tools and fixtures during work

(2) Contamination source at launch and in orbit

a. Molecular contamination

(i) Sublimation and outgassing from spacecraft (including adhesives), reaction products of spacecraft surface materials with atomic oxygen

(ii) Plume from propulsion system

(iii) Leakage fluid during fluid QD (quick disconnector) operation

(iv) Leakage and dump of liquids and gases (refrigerant, propellant, experimental exhaust, airlock exhaust, exhaust from life maintenance system, etc.)

(v) Leakage from pressurized units

(vi) Outgassing from vent holes on MLI, components, honeycomb panels, etc.

b. Particulate contamination

(i) Fine particle nozzle material caused by the injection of propulsion system

(ii) Solid propellant combustion slag

(iii) Fine particles from a spacecraft generated by the influence of the space environment (reaction products of spacecraft surface materials and atomic oxygen, ejectors, etc.)

(iv) Plume from propulsion system

(v) What is generated from the unfolded object at the time of unfolding

(vi) Products generated from moving parts such as mechanisms and motors

4.2.3.2 Contamination profile

In the contamination control plan, the conditions related to contamination in each phase of ground, launch and in-orbit operations (this includes cleanliness, pressure, humidity, temperature, cleaning work, equipment outline, etc.) shall be proposed as a contamination profile and maintained throughout development.

4.2.3.3 Impact of contamination on performance

By clarifying the correlation between contamination and performance degradation, the limit value of contaminants allowed for sensitive hardware shall be determined. The value of cleanliness requirements shall be estimated early and further refined through performance analysis.

4.2.4 Contamination prediction

Analysis of the movement and deposition of contaminants in all phases of ground and orbital operations shall be done. When the cleanliness exceeds the specifications requirements, protective measures shall be taken. The parameters required for predictive analysis are view factor, outgassing

behavior of suitable materials, condensation behavior and significant surface temperature, outgassing temperature, surface reflection, scattering interaction in neutral atmosphere, electrical interactions with surrounding space plasmas, surface interactions with space radiation, especially incident ultraviolet photons, etc.

4.2.5 Contamination budget

Contamination budgets for both particulate and molecular forms shall be determined based on contamination profiles and cleanliness requirement specification of the hardware. Contamination budgets shall take into account not only the results of predictive analysis, exposure time and use of protective covers but also the possibility of restoring cleanliness between ground and orbital operations. Cleaning methods and methods for maintaining cleanliness shall be considered throughout all phases of the project. The budget shall include BOL and EOL cleanliness.

4.2.6 Design considering cleanliness

By establishing methods for maintaining the cleanliness of sensitive hardware, reducing sensitivity to contamination, and facilitating cleaning, outline of the design considering cleanliness shall be described in the contamination control plan. Also, that process shall be included in the contamination control plan.

The following items shall be discussed, and necessary measures shall be taken based on the cleanliness requirement specifications and contamination budget.

(1) Orientation and location of sensitive hardware
(2) Reduction of outgassing materials use
(3) Application of exhaust vents, baffles and shields
(4) Temperature control of outgassing generating hardware
(5) Cleaning process design
(6) Sealing of contamination sources
(7) Baking
(8) Human metabolism, waste treatment
(9) Other methods to prevent contaminants from being generated, left behind, or brought in

Ground support equipment located at a close distance or in contact with a spacecraft in the room shall not contaminate the spacecraft. For the cleanliness of the part that directly interfaces with the spacecraft, the cleanliness specified for the spacecraft shall be considered. Contamination control during ground work is described in Section 4.4.

4.2.6.1 Configuration

When designing a spacecraft, the layout such as configuration and onboard performance, etc. shall be designed by considering the following items.

a. Minimization of view factor (identified target to be contaminated, solar paddle, etc.)
b. Component that is susceptible to particulate contamination and component that may cause particulate contamination.
c. Potential sources of molecular contamination
d. Workability for cleaning, inspection, etc.

4.2.6.2 Contamination prevention

When sensitive hardware contamination by thruster plumes, etc. is unavoidable in orbit, it shall be protected with plume shields, covers, etc.

In addition, if sensitive hardware contamination is predicted in the ground environment, the sensitive hardware shall be protected by a protective cover, purging with dry clean gas, or either.

4.2.6.3 Decontamination

Sensitive hardware shall be as decontaminated (cleaned or baked) as possible by just before launch. In addition, component, etc. shall have a function that can bake in order to remove contamination by condensable volatile substances (especially moisture) of sensitive hardware that is maintained at a low temperature in orbit. In addition, sufficient operating time shall be secured for this purpose.

4.2.6.4 Design confirmation

If required, a design that takes cleanliness into consideration shall be included in the normal design review.

In addition, the review results related to the application of this Standard at the design reviews, etc. shall be reflected in related documents such as specifications, procedure manuals, and control criteria.

4.2.7 Material and process selection

Materials and processes shall be selected to meet other functional requirements and minimize contamination. The basic screening items for materials are outgassing, offgassing, particle generation, fungal growth, hygroscopicity, brittleness, etc.

For areas where contamination control is required, materials that do not generate dust or peel off and materials that do not generate particles must be used.

For materials with questionable properties, it shall be confirmed by testing.

4.2.7.1 Outgassing

Material selection shall be referred to 2.2 in this document. The test method shall be conducted by the test approved by ASTM E 595, ECSS-Q-ST-70-02C or JAXA authorized standard. Materials with a TML of less than 1.0%, an RML of less than 1.0%, and a CVCM of less than 0.1% are generally considered low outgassing materials. These values do not give acceptance criteria for material selection. In general, even materials that are considered low outgassing can cause deterioration of contamination sensitive surfaces. Material selection guidelines based on more stringent conditions may be required to meet mission and performance requirements. The material should be selected in consideration of the operating temperature, mass and surface area.

[Conditions that increase the risk of contamination]
When used under the following conditions, even materials with low outgassing can cause contamination.
- Close to or in sight of contamination sensitive surfaces
- Used near the cold surface or is in the field of view from the cold surface.
- The amount used is larger.
- Operated at a higher temperature than the surrounding surface.

[Conditions that reduce the risk of contamination]
When used under the following conditions, the effects of contamination will be small even for materials with a large amount of outgassing.
- Far from or out of sight of contamination sensitive surfaces
- Far from the cold surface or out of sight
- The amount used is small.
- Operated at a lower temperature than the surrounding surface.

WVR may be subtracted from TML in consideration of the performance requirements of the space system, the application of materials, and the functional requirements of the spacecraft (refer to 4.2.7.4). The validity of material selection is verified by contamination analysis (refer to 4.2.5). Materials that do not meet the material selection guidelines can also be used as long as the predicted contamination level meets the contamination budget. (refer to 4.2.4, 4.2.5)
Note: Long-term total outgassing emissions based on ASTM E 1559 (Applicable Document (21)) or equivalent outgassing rate testing can be applied to material selection guidelines.

4.2.7.2 Total mass loss ratio of moisturized material

Some materials may contain a large amount of adsorbed water that contributes to the total mass loss ratio (TML). When the water vapor emitted as outgassing is not critical to sensitive hardware, the recovered mass loss (RML), which is the total mass loss (TML) minus the outgassing moisture, is used instead of the total mass loss (TML). The recovered mass loss (RML) is given by the following equation. The WVR in the formula represents the "water vapor regained".

RML = TML - WVR

4.2.7.3 Metal material

Since metal material becomes a source of outgassing and particles due to corrosion, corrosion-resistant material shall be used, or appropriate surface treatment and anticorrosion treatment by coating shall be done. In addition, since the combination of dissimilar metals is also involved in the occurrence of corrosion, in principle, appropriate combination according to MIL-STD-889 shall be made. Of the metal materials, osmium and silver react with atomic oxygen and oxidize. Since silver oxide may peel off and cause particulate contamination, it shall be applied appropriate surface treatment, anticorrosion treatment such as coating, etc. and not exposed to the surface.

4.2.7.4 Non-metal material

Non-metallic materials shall be listed without omission. The list shall include the total mass loss (TML), collected volatile condensable material (CVCM), amount used, place of use, etc. However, when there is a request of each project regarding the scope and contents of the list, it shall be followed the request. For non-metal materials, materials with as little outgassing and offgassing as possible shall be selected. Using organic materials that induce the growth of bacteria and mold shall be avoided as much as possible.

4.2.7.5 Fluid

For the fluid used for the propulsion system, cooling system, hydraulic/pneumatic system, etc. of the spacecraft, fluid whose cleanliness is controlled by official standards such as ISO 15859 shall be selected.

4.2.7.6 Process

All processes and control methods that affect cleanliness shall be identified. For critical processes, it shall be based on individual project management requirements. For parts used for assembly, they shall be removed particulate contamination to the level of visibly clean in advance.

In addition, parts and materials used for systems or components where outgassing is critical shall be baked according to the contamination control plan. These cleanliness by inspection shall be checked before assembling or bringing them into a clean area.

4.2.7.7 Quality control

Appropriate quality control processes shall be maintained to verify the properties of the material. The processes and compositions of commercial materials may not be well controlled to meet the requirements of space systems. The specifications of the quality control process shall be determined on a case-by-case basis. ASTM E 595 or ECSS-Q-70-02 can be used as a quality control test for the outgassing properties of a material.

4.3 Biocontamination

4.3.1 Overview

The organisms that cause biocontamination are fungi, yeast, viruses and bacteria. They breed both on the ground and in flight, producing contaminants. They also enter on the ground during manufacturing, integration and testing, as well as during transportation and operation. Human excrement and metabolites accelerate the growth of micro-organisms through the intervention of water or nutrient sources. Hardware cleanliness requirements can be applied to dead organisms, by-products as chemicals and particles, and living organisms as well as metabolites from the organisms. In addition, it is necessary to take measures in the clean room of the range because there is a possibility of invasion of birds and insects.

4.3.2 Hardware contamination by micro-organisms

(1) Micro-organisms produce substances through metabolic and/or biological activity. These substances cause hardware contamination or corrosion.
(2) Preventative measure against micro-organism contamination is to eliminate water and nutrient sources. It is difficult to prevent the growth of micro-organisms, especially in a room with an air circulation device, but countermeasures include installing a high-performance filter and efficient cleaning. Also, designing hardware that can be easily cleaned is an important countermeasure.

4.3.3 Handling of sterilized hardware

(1) The sterilization procedure shall include the following procedures in a way that meets the cleanliness requirements of the hardware.

a. Procedures to avoid contact with contaminated material

b. Procedures for avoiding contact between air and biological aerosols in purge gas

c. Procedures to avoid contact with personnel

(2) The ground handling process shall be planned to meet the sterilization requirements of the hardware. This shall include maintaining a sterilized environment such as sterilized packaging, sterilized isolation and sterile rooms. Refer to ISO 14698-1 for details. In addition, the procedure that meets the hardware requirements shall be included in the contamination control plan or referred.

(3) In ground operations, it shall be monitored to ensure that the cleanliness of the hardware and the environment meet the requirements. Refer to ISO 14698-2 for explanation and evaluation of biocontamination data and ISO 14698-3 for measuring efficiency of cleaning and sterilization processes.

(4) Personnel clothing shall be considered to protect personnel from dangerous contaminants and prevent personnel from contaminating hardware.

4.3.4 Planetary protection

Refer to Chapter 4, Management Requirements, Chapter 5, Technical Requirements, and Appendix A. (Applicable) Project Planetary Protection Requirements of, "Planetary Protection Program Standards (JMR-014) ".

4.4 Contamination control during ground works

4.4.1 Education and training of personnel

Personnel who handle sensitive hardware shall be educated and trained according to the procedures confirmed in advance for each contamination control plan. Refer to Section 4.3 Personnel and Annex C Personnel of ISO 14644-5: 2004 for additional information on personnel.

4.4.2 Clean room selection and cleanliness control

(1) Appropriate environment for manufacturing, assembling, integrating and testing the hardware shall be selected based on the contamination budget in Section 4.2.5.

a. Clean rooms shall be selected based on hardware cleanliness requirements, operating procedures and exposure time.

b. The permissible concentration of particles suspended in the air shall be specified in the air quality class in accordance with ISO 14644-1.

c. Operation and hibernate procedures shall be specified to meet hardware cleanliness requirements.

d. In order to meet the cleanliness requirements of the hardware, a clean booth or the like specially controlled for cleanliness should be provided in the clean room as needed.

e. Monitoring of contaminants floating in the air and on the surface while the clean room is in operation shall be defined in consideration of spacecraft performance requirements and risks / costs.
f. Materials, parts, hardware and test equipment brought into the clean room shall meet the cleanliness requirements of spacecraft hardware.

(2) In the contamination control plan, taking into account facility failures such as clean room power down, cooling water and component damage, appropriate operating procedures to prevent spacecraft damage shall be clarified with considering risks/costs. Also, single failure mechanisms including human error shall be analyzed and eliminated.
(3) Clean room facility shall be operated according to procedures including cleaning, clean room management, cleanliness monitoring, and equipment maintenance. The clean room shall be cleaned to meet the cleanliness requirements of the spacecraft.
(4) ISO 14644-4 shall be referred to for the design, construction and start-up of the clean room, and ISO 14644-5 shall be referred to for the operation as supplementary information.

4.4.3 Garments (clothing for clean room)

4.4.3.1 General

The main purpose of wearing garments is to prevent contaminants produced by personnel from reaching the product and to protect personnel from harmful substances.

4.4.3.2 Selection of garments

(1) Based on hardware cleanliness requirements, clean room airflow schemes and staffing for the hardware, a frock coat type usually with a cover-all type with a hood and high-top shoe cover (boots), or with a partial head cover and shoe cover shall be selected. However, the frock coat type has an open lower part, and there is a higher risk of causing particle accumulation on the floor and hardware surface and deterioration of air quality than the coverall type, it shall be not recommended when working on hardware or when hardware cleanliness requirements are strict.
(2) Good antistatic properties, breathability, moisture permeability, dust resistance, abrasion characteristics and low dust generation properties shall be had. It also shall have high resistance to washing and dry cleaning.

4.4.3.3 Other

(1) Clean the garments regularly or when it gets dirty. It is desirable to set the cleaning frequency in the contamination control plan for each project.

(2) Additional Information

Refer to Section 4.2 of ISO14644-5: 2004 and Appendix B for additional information on the selection and use of garments.

4.4.4 Management of facility, ground support equipment, materials and auxiliary materials

4.4.4.1 Management of facility, ground support equipment, tools, etc.

Facility equipment, ground support equipment, tools, etc. used for work in the clean area shall not contaminate the environment of the clean area and sensitive hardware. The management of facility equipment, ground support equipment, tools, etc. is basically the management of contamination sources.

When using facility equipment, ground support equipment, tools, etc., necessary maintenance shall be performed before use and cleaning shall be performed if there is dirt so that the work environment and the object to be contaminated are not contaminated.

The connection surface that comes into direct contact with the contaminated object shall be cleaned in advance and protective measures shall be taken to prevent the contaminated object from becoming contaminated.

If the outer surface cannot be kept clean, cover or seal the entire surface with a sheet that does not generate contaminants as much as possible, and take protective measures so as not to contaminate the work environment in the clean room. Facilities used to handle sensitive hardware will be managed so that the hardware can be maintained at the specified cleanliness by taking necessary measures including prevention of contamination by contaminants scattered by the airflow from the fan. In facilities where sensitive hardware is tested, install a witness plate, etc. as necessary to monitor the cleanliness of the environment in which the equipment is exposed.

4.4.4.2 Gas control

The cleanliness of gas is expressed by the amount of impurities. The purge gas used for rocket fairing, vacuum equipment, containers, etc. shall be confirmed in advance that the vapor of particles and organic substances is equivalent to that of clean air. And so as not to reduce the cleanliness of the product, gas shall be controlled by analyzing it as necessary before filling the machine at the time of acceptance that it satisfies the specified purity and impurities (particles, moisture, etc.) requirements.

4.4.4.3 Liquid control

Liquids used in spacecraft include propellants (oxygen, hydrogen, dinitrogen tetroxide, monomethylhydrazine, hydrazine, kerosine, etc.), pseudo-propellants, hydraulic oils, drinking water in manned systems, sanitary water, cooling water, etc. So as not to reduce the cleanliness of the product, they shall be controlled to meet the specified purity and impurity (particles, hydrocarbons, moisture, etc.) requirements at the time of acceptance, transfer to the storage tank, and before filling into the spacecraft, by analysis as necessary.

So as not to reduce the cleanliness of the product, the cleaning agent used for the final cleaning shall be controlled by analysis to satisfy the specified requirements of particles and non-volatile residue (NVR) at the time of receiving the cleaning agent l and during use at an appropriate frequency.

4.4.5 Cleanliness monitor for flight hardware and its vicinity

Cleanliness shall be measured and recorded at the methods and intervals determined in accordance with the contamination control plan. Requirements for monitoring suspended particle concentrations in clean rooms are contained in ISO 14644-2. Additional measurement methods are described in ISO 14644-3.

4.4.5.1 Measurement of surface cleanliness

(1) Measurement of molecular contamination

Methods for measuring molecular contamination include mass method, quartz crystal microbalance (QCM), calorie method, photoelectron spectroscopy, infrared spectroscopy, and the like. When applying, the one that suits the purpose shall be selected based on the characteristics of each method.

(2) Measurement of particulate contamination

Methods for measuring particulate contamination include visual inspection, optical measurement (for example, microscope, light scattering method) and the like. When applying, the one that suits the purpose shall be selected based on the characteristics of each method.

4.4.5.2 Air quality measurement

Methods for measuring air quality include a film filter sampling method, a light-scattering method, a dark field photography method, and the like. When applying, the one that suits the purpose shall be selected based on the characteristics of each method.

4.4.5.3 Gas cleanliness measurement

A film filter sampling, a light scattering method, or the like is used for measuring the particles, and a moisture meter or a dew point meter is used for measuring the water concentration. When measuring impurity gas and organic vapor, infrared spectrophotometer, gas chromatograph, mass spectrometer, or a combination thereof shall be used as necessary. The purity of the gas shall be confirmed by the manufacturer's inspection report at the time of purchase and regularly inspected.

4.4.5.4 Liquid cleanliness measurement

Measurement of propulsion agents (oxygen, hydrogen, dinitrogen tetroxide, monomethylhydrazine, hydrazine, kerosine, etc.), pseudo-propellants, hydraulic oils, drinking water, sanitary water and cooling water in manned systems, and particles of cleaning agents (IPA, deionized water, etc.), are conducted by membrane filter sampling, light scattering method, or the like. The non-volatile residue is measured by the mass method. Free water is visually inspected. The resistivity, dissolved oxygen and other dissolved gases, total organic carbon, water, pH and viscosity shall be analyzed using dedicated analyzers.

4.4.5.5 Evaluation of data error and accuracy

Since the measurement of cleanliness deals with a very small amount of physical quantity, sufficient evaluation shall be made for measurement error and analysis accuracy.

4.4.5.6 Statistical analysis of data

For measurement data of particle number, when the cleanliness is near the borderline of the required value, it shall be analyzed by a statistical method. This is not the case when it is significantly better than the requirement.

4.4.6 Flight hardware control

Contamination control shall be conducted to meet hardware cleanliness requirements and contamination budgets. ISO 14952, especially ISO 14952-3, which determines cleanliness, is applied to fluids. The following items shall be specified in the contamination control plan.

(1) Check that the cleanliness of the surrounding environment is within the permissible range by monitoring.

(2) Procedures for dealing with sensitive hardware in uncontrolled areas.

(3) Contamination prevention measures for sensitive hardware such as thermal control surfaces, optical system equipment, solar cell panels and subsystems composed of them (implementation of whole or partial nitrogen gas purging, installation of dustproof covers, etc.).

(4) Washing/cleaning procedure

Clarify the cleaning / cleaning procedure, method, frequency, and cleaning agent, including the skills, precautions, cloth, equipment, equipment specifications, and timing of use, which are necessary to satisfy the cleanliness requirements.

For cleanliness and cleanliness inspection after cleaning, the requirements of ISO 14952-2 shall apply. Cleaning and cleaning procedures when sensitive hardware is contaminated.

(5) Baking

Baking of flight hardware is effective in reducing outgassing rates and potential contaminants. Bakeout is performed in a vacuum or in a flow controlled gas environment such as clean and dry gaseous nitrogen. Not all baking procedures are equivalent in terms of results. Engineering analysis and judgment shall be used to select a bakeout procedure that is cost effective and meets system performance requirements. Baking can be performed component-by-component at all levels of hardware assembly, depending on analysis and system performance requirements. When there is a hardware that is sensitive to the bakeout object, special care should be taken to prevent cross-contamination.

Assigning conditions such as the level of vacuum, pressure of fluidized gas, temperature, time, monitoring method, etc., the baking procedure is specified in the contamination control plan as necessary.

(6) Purge

Clean gas can be used to purge flight hardware to keep contaminants out of critical components. Clean nitrogen, helium, argon and air are used. Consider safety. ISO 15859-3, 15859-4 and ISO 15859-9 can be applied. Additional filtration may be required during use to meet cleanliness requirements. The purge gas requirement, purge time and permissible non-purge time should be included in the applicable CCCP.

(7) Clarify the range of systems that require contamination management.

For equipment that handles fluids such as propulsion systems that require cleanliness of the internal area, it is stipulated that the cleanliness of the filled fluid should be inspected at the

connection port as necessary before and after the fluid filling work.

Procedures for confirming that the cleanliness requirements are met, guaranteeing the cleanliness of the equipment used during filling work, and filter specifications.

4.4.6.1 Contamination prevention for each phase

(1) Parts manufacturing phase

Unless otherwise specified, parts shall be manufactured in a conventional industrial area or a controlled work area. When there are provisions that require cleaning during manufacturing, it shall be complied with the regulations. It shall be made sure that the parts to be sealed are in a visibly clean before the sealing process.

After completing the parts and before transferring them to the storage or assembly area, it shall be checked that they are clean after removing particulate contamination such as solder aids, oil, grease and work debris. When storing parts, they shall be sealed and protected with approved packaging.

(2) Component assembly/testing phase

Unless otherwise specified, component assembly and testing shall be performed in an environment that meets the requirements of Section 4.4.2. However, this does not apply when target range of contamination control is a sealed device.

Care shall be taken during the thermal vacuum test as there is a high risk of molecular contamination.

The outside of the packaging shall be cleaned before bringing it into the front room of a clean room. For sealed packaging, the packaging (double packaging is only on the outside) shall be removed in the anterior chamber before carrying in.

Equipment shall be covered and protected when not assembled or tested.

(3) Subsystem/system assembly/testing phase

Subsystem/system assembly and testing shall be performed in a clean area controlled by the specified air quality.

Areas that are susceptible to contamination shall be protected with a cover, etc.

Care shall be taken during the thermal vacuum test as there is a high risk of molecular contamination.

Also, any work that generates contaminants, such as cutting or using lubricating oil shall not be performed. When implementing it, it shall be made sure that it does not affect others. Particles, oils and fats that have adhered during assembly shall be made sure to remove.

The outer surface of harnesses, equipment, etc. mounted inside the spacecraft shall be inspected and cleaned before the spacecraft is closed out.

(4) Launch range phase

The following items shall be specified in the contamination control request.

a. Air conditioning requirements in the fairing when storing the spacecraft in the fairing and moving it.

b. Regulations on when to remove the dust cover and/or when to stop the nitrogen gas purge before launch.

c. For flight hardware with sensitive surfaces such as thermal control surfaces, optical system, and solar cell panels, cleaning regulations of final visual inspection before launch and when contamination is found.

4.4.7Packing, transportation and storage

Regarding packaging, transportation, and storage, it shall be stipulated in the contamination control plan and included at least the following items.

4.4.7.1 Packing

Packaging is used to protect the hardware during storage and transportation. Packaging materials shall not increase hardware contamination and contain volatile or mobile contaminants. The packaging material is desirable as an antistatic material because it prevents the adhesion of particulate contamination due to charging.

4.4.7.2 Storage

Proper contamination protection of packages and products shall be done during the intended storage period at the storage location.

4.4.7.3 Transportation

Containers shall be used during transportation. The material of the container shall be selected in consideration of volatility, contaminants of concern, transportation method and transportation environment.

4.5 Launch and operational phase

In the contamination control plan, after identifying the spacecraft operations that lead to the occurrence of contamination in launch and on-orbit, appropriate management such as temperature

control and baking shall be specified.

4.6 Product assurance

Complying with the contamination control plan, quality assurance activities to maintain and guarantee the cleanliness required for systems and components shall be performed. For this quality assurance activity, JMR-005 (Quality Assurance Program Standard) or JMR-013 (Quality Program Standard (Basic Requirement JIS Q 9100)) is applied.

5 DETAILED REQUIREMENTS

Not applicable.