
**Space systems — Paints and varnishes
— Processes, procedures, and
requirements for coating materials
and coatings**

*Systèmes spatiaux — Peintures et vernis — Procédés, modes
opératoires et exigences concernant les produits de peinture et les
revêtements*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Nowadays, there are a large number of paints and varnishes (coating materials), on the basis of which coatings for space systems products can be developed and manufactured.

For the use of coating materials, requirements are additionally imposed on the selection processes and procedures for verifying coating materials, surface preparation before painting, application conditions and quality control of coatings.

The main purpose of this document is to harmonize the requirements of existing international and national standards in this area.

Manufacturers of space systems products usually prepare coating materials for application and form coatings under the required operating conditions; therefore, this document aims to optimize the processes of verification, preparation and application of coating materials to improve the quality of painting.

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Space systems — Paints and varnishes — Processes, procedures, and requirements for coating materials and coatings

1 Scope

This document establishes the main requirements for:

- a choice of coating materials and coatings for space applications;
- processes and procedures for the verification of coating materials;
- processes of preparation and quality control of the painted surface;
- the quality control of the applied coatings.

This document also describes the causes of possible defects in coatings.

This document is applicable to coating materials and coatings based on them; it is intended for use by manufacturers of space systems products for various surfaces of spacecraft's and its constitutive parts (on-board systems, facilities, tools, electronic component base products) with long active lifetimes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 1514, *Paints and varnishes — Standard panels for testing*

ISO 4628-8, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 8: Assessment of degree of delamination and corrosion around a scribe or other artificial defect*

ISO 9000, *Quality management systems — Fundamentals and vocabulary*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 10794, *Space systems — Programme management — Material, mechanical parts and processes*

ISO 16691, *Space systems — Thermal control coatings for spacecraft — General requirements*

ECSS-Q-ST-70-71C, *Space product assurance. Materials, processes and their data selection*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9000 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

coat

layer of a *coating material* (3.3) resulting from a single application

Note 1 to entry: For fillers the word “coat” is used instead of “film”.

[SOURCE: ISO 4618:2014, 2.49]

3.2

coating

layer formed from a single or multiple application of a *coating material* (3.3) to a *substrate* (3.12)

[SOURCE: ISO 4618:2014, 2.50.1]

3.3

coating material

product, in liquid, paste or powder form, that, when applied to a *substrate* (3.12), forms a layer possessing protective, decorative or other specific properties

Note 1 to entry: The term “specific properties” means insulating, anti-corrosive, thermal control and other properties.

[SOURCE: ISO 4618:2014, 2.51, modified — Note 1 to entry has been replaced by a new one.]

3.4

coating process

method of application of a *coating material* (3.3) to a *substrate* (3.12)

[SOURCE: ISO 4618:2014, 2.53]

3.5

coating system

combination of all *coats* (3.1) of *coating materials* (3.3) which are to be applied or which have been applied to a *substrate* (3.12)

Note 1 to entry: The actual system can be characterized by the number of coats involved.

Note 2 to entry: See also *coating* (3.2).

[SOURCE: ISO 4618:2014, 2.54]

3.6

flow time

relative viscosity

time that elapses from the moment when the material under test starts to flow from the orifice of the filled flow cup to the moment when the flow stream of material first breaks off close to the orifice

[SOURCE: ISO 2431:2019, 3.1, modified — The symbol “*t*” has been removed; the alternative term “relative viscosity” has been added.]

3.7

functional coat

coat (3.1) of *coating system* (3.5) with specific properties, designed to perform additional functions

Note 1 to entry: Additional functions may include: corrosion protection, protect from UV radiation and from other types of radiation, low and high temperatures and also from other factors of space environment.

3.8

normative documentation

specifications, standards, rules or instructions, to which adherence is required through citation in the design documentation or the construction, fabrication, manufacture, purchase or production documentation for the manufacture and operation of the facility, system or equipment

Note 1 to entry: In this document, the term is applied to the documentation for a specific *coating material* (3.3) or *coating* (3.2).

[SOURCE: ISO 16159:2012, 2.11, modified — Note 1 to entry has been added.]

3.9

paint

pigmented *coating material* (3.3) which, when applied to a *substrate* (3.12), forms an opaque dried film having protective, decorative or specific properties

Note 1 to entry: For coating materials with protective and specific properties in *normative documentation* (3.8), the term "enamel" may be used for a liquid or paste-like pigmented coating material in which the coating medium is a solution of the film-forming substance of the coating material in organic solvents.

[SOURCE: ISO 4618:2014, 2.184, modified — Note 1 to entry has been added.]

3.10

priming coat

first coat (3.1) of a *coating system* (3.5)

Note 1 to entry: Priming ensures better adhesion of *coating material* (3.3) to the surface, increases *paint* (3.9) durability, and provides additional protection for the material being painted.

[SOURCE: ISO 4618:2014 2.207, modified — Note 1 to entry has been added.]

3.11

ready-to-apply coating material

coating material (3.3) or coating material after mixing of its certain components (multicomponent coating material) and after dilution if it is necessary with certain solvents and/or with certain dilutants according to *normative documentation* (3.8) and that is ready to apply by certain painting methods

3.12

substrate

surface to which a *coating material* (3.3) is applied or is to be applied

[SOURCE: ISO 4618:2014, 2.244]

3.13

surface preparation

physical and/or chemical treatment of the surface to be painted in order to clean it and improve the adhesion of the *coating material* (3.3) to the surface to be painted

3.14

thermal control coating

TCC

coating (3.2) that is used to maintain certain temperature conditions of an object by way of establishing the balance between the heat absorbed from an environment and/or emitted by internal heat sources and the energy radiated by object's surface in an environment

Note 1 to entry: In this document, the term refers to TCC based on *coating materials* (3.3).

[SOURCE: ISO 16691:2014, 3.1.15, modified — Note 1 to entry has been added.]

3.15

varnish

transparent *coating material* ([3.3](#))

Note 1 to entry: See also clear coating material (ISO 4618:2014, 2.47).

[SOURCE: ISO 4618:2014, 2.266, modified — Note 1 to entry has been replaced by a new one.]

4 General provisions

4.1 General requirements for coating materials and coatings

4.1.1 To apply coatings for products of space systems, coating materials shall be selected that meet the requirements for their operation in space environment conditions.

4.1.2 For products of space systems, coatings with the following specific properties are used:

- a) thermal control;
- b) electrically conductive;
- c) electrically insulating;
- d) thermal resistant;
- e) anticorrosive;
- f) chemically resistant;
- g) resistant to space environment factors.

4.1.3 Coating materials shall meet the requirements of the normative documentation, be manufactured according to technological documentation for each material, and be delivered to the customer with quality document according to the delivery documentation, taking into consideration specific national and local requirements.

4.1.4 The delivery documentation for a particular material specifies the scope of the coating material, specification and conditions for coatings' formation.

4.1.5 A warranty period of storage shall be established for the coating materials.

4.1.6 To confirm the durability (service life) of coatings as part of the product, the following tests shall be carried out:

- accelerated aging tests to simulate storage in land conditions (accelerated climatic tests) according to ISO 4628-8 and ISO 9227;
- accelerated simulation tests of space environment factors (atomic oxygen, electron, proton, ultraviolet radiation, thermal cycling);
- tests to determine the outgassing.

4.1.6.1 In the process of testing, the parameters given in [Table A.1](#) are controlled in accordance with the established requirements for a specific coating.

4.1.6.2 Test methods, their scope and sufficiency shall be selected depending on the operating conditions of the coatings in the composition of the product and depending on the requirements of the normative documentation.

4.1.7 The main outgassing characteristics of coatings for space applications are as follows:

- total mass loss (TML);
- recovered mass loss (RML);
- collected volatile condensable materials (CVCM).

Materials having TML of less than 1,0 %, RML of less than 1,0 % and CVCM of less than 0,1 % are generally considered as low-outgassing materials.

The outgassing requirements shall be based on the quantity of material concerned and the specific environmental conditions.

When contamination-sensitive products are involved or for materials in the vicinity of cryogenic surfaces, more stringent requirements shall apply in order to compensate the missing details.

4.1.8 Coating materials used for space systems products shall be subjected to the procedures of verification and validation in ISO 10794 and ECSS-Q-ST-70-71C.

4.1.9 To obtain coatings with specified characteristics, coating materials shall meet the requirement of the normative documentation for coatings; for example, thermal control coatings shall meet the requirements of ISO 16691.

4.1.10 For particular coatings, additional requirements for coating materials apply according to the normative documentation and ECSS-Q-ST-70-31C.

4.2 Main processes and procedures to manufacture coatings

4.2.1 For the production of coatings, the main processes and procedures are:

- a) verification of coating materials in accordance with the normative documentation;
- b) preparation of the surface before painting;
- c) preparation of coating materials for the application of a coating;
- d) filling layer applying (if the coating's system includes this layer):
 - 1) drying;
 - 2) operational inspection;
- e) priming coat applying (if the coating system includes this coat):
 - 1) drying or curing (depending on the physico-chemical properties of coating materials);
 - 2) operational inspection;
- f) functional coat applying:
 - 1) drying or curing (depending on the physico-chemical properties of coating materials);
 - 2) operational inspection;

NOTE The coating system may consist of several functional coats.

g) quality control applied coating.

4.2.2 In violation of the integrity of the coating in cases provided by the normative documentation for a specific coating, repair work may be performed with a subsequent reinspection.

4.2.2.1 If the area to be restored is less than 10 % of the total surface, localized repairs may be performed.

4.2.2.2 If the area to be restored is more than 10 % of the total surface, the coating layer (coating) is removed from the total surface and reapplied according to [4.2.1](#).

4.2.3 The following requirements shall be established for the processes performed:

- a) requirements for production facilities;
- b) requirements for production equipment;
- c) requirements for application process;
- d) requirements for storage and transportation;
- e) requirements for personnel;
- f) requirements for measurement tools and for test equipment;
- g) requirements for personal protective gear;
- h) requirements for industrial wastes disposal.

Specific requirements related to the specifics of production shall be reflected in the normative documentation.

5 Verification of coating materials

5.1 Verification of coating materials (purchased products) is carried out to check the conformity of the product quality with the normative documentation, the period and method of storage for the material and to prevent the product launch of non-conforming products.

5.2 Verification of coating materials shall include the following procedures:

- a) a check-up during the acceptance test (determination of the main coating material properties according to the normative documentation and to the document of quality);
- b) a check-up at the end of the maintenance storage period (if it is allowable according to the normative documentation for the material).

5.3 Indicators being monitored and coating materials properties, type, and volume of inspection shall be determined in each case by the customer on the basis of the importance of each indicator.

5.4 Verification of coating materials, depending on their purchase volume, should be carried out by continuous or selective inspection of a batch. Each of these types of control (tests) shall include quantitative measurement and visual inspection methods, depending on the means of obtaining information, its reliability, and sufficiency.

5.5 Measuring or visual verification methods of purchased products shall be used in accordance with the normative documentation for coating materials. Measuring results and visual identification results shall be consistent with estimated normative documentation parameters.

5.6 Measuring verification methods shall be used in those cases when higher reliability of the obtained information is required. Measurement results shall be consistent with the parameters stated in the normative documentation.

5.7 Non-conforming products shall be identified by a non-conformance label and placed in a segregated place to prevent unintentional use thereof until a further decision is taken.

5.8 Non-conforming products shall be issued a claim or complaint.

5.9 Coating materials after the expiration of the storage period may be used only after rechecking for compliance with all the main indicators established in the normative documentation, provided that this indication is contained in the normative documentation for a specific coating material.

6 Preparation of surfaces before painting

6.1 General conditions for the preparation of surfaces before painting

The quality of a coating shall be ensured by proper and thorough surface preparation. The surface preparation methods depend on the properties of the material to be painted and on the specific design features of the product.

6.2 Preparation of metal surfaces

6.2.1 The main purpose of metallic surface preparation before painting is to remove substances that interfere with colouring and accelerate corrosion processes.

6.2.2 The main factors affecting these characteristics are the presence of rust, dross, greasy stains and hard to get off pollutions, soluble oils mixed with metal chips and dust, carbon deposits, grinding and polishing pastes, and conversion coatings.

6.2.3 The prime objective of the preparation is to obtain a surface that provides the required adhesion to the metal substrate of the coating.

6.2.4 Surface preparation consists of a series of operations:

- a) cleaning from contaminants: the cleaning may be performed using mechanical and chemical (aqueous washing solutions, alkaline rinses, acid solutions, emulsion cleaners and emulsions, solvents) methods;
- b) mechanical processing: mechanical processing of products' surfaces is performed to improve adhesion properties of coatings by using hand-guided, mechanical hand tools, special equipment, and also by abrasive-jet machining.

6.2.5 When choosing the surface preparation method, the initial condition of the surface, material properties, and product characteristics shall be taken into account.

6.2.6 Surface areas inaccessible to power tools are prepared manually. The treatment shall be carried out in such a way that no damages or surface defects like scratches, dents, etc. will be on the surface.

6.2.7 A special chemical treatment like phosphating, chromating and oxidation is performed after cleaning to impart additional corrosion resistance to the surface. As a result of such a surface treatment, inorganic non-metallic coatings are formed. They improve the adhesion and durability of the coating applied above.

6.2.8 No burrs, sharp edges, welding splashes, soldering flows, thermal damages, flux residue are allowed on the surface to be coated. The burrs, sharp edges, welding splashes, and soldering flows may exist on surfaces of product details (without specific requirements for appearance) if it is stated in the corresponding normative documentation.

6.2.9 Roughness, waviness parameters and parameters of the substrate are stated in each case separately depending on specific requirements for the product surface.

6.2.10 After the preparation of the surfaces, the products shall be painted immediately or within time as indicated in the coating material datasheet (normative documentation) including margins.

6.2.11 Conditions which exclude the appearance of any type of pollution and corrosion shall be performed during and after the surface preparation. The shelf period after the surface preparation and before the coating process is limited and should be regulated by the normative documentation.

6.3 Preparation of non-metallic surfaces

6.3.1 Preparation processes of non-metallic surfaces depend on material properties, specific design features of the product and are performed according to the manufacturer's documentation and include the following main procedures:

- a) processing with abrasive materials (grinding skins), in exceptional cases by abrasive-jet machining;
- b) dust removal;
- c) degreasing;
- d) drying.

6.3.2 On the prepared non-metallic surface after treatment and degreasing, there should be no glossy areas, white bloom, resin deposits, and residues of separating layers, grease, moisture, mineral oils, and other contamination.

7 Preparation of coating material

7.1 It is presupposed that the preparation of the coating material, the conditions and modes of application are controlled for compliance with the normative documentation for a specific coating material.

7.2 The preparation of coating material, reaching the working viscosity, filtering, and implementation of hardeners shall be performed after the material temperature is the same as the facility temperature in accordance with the normative documentation.

7.3 The container with a coating material shall be tightly sealed to avoid solvent evaporating and also water, dust, dirt entries since it can lead to the paint material degradation.

The container with a coating material before the opening thereof shall be cleaned from dust with a cotton cloth to avoid contamination of the material.

7.4 Before usage, the coating material shall be thoroughly mixed until the pigment is evenly distributed and the sediment disappears.

7.5 Before applying two-component (multicomponent) coating materials, a hardener or polymerization initiator shall be added into a semi-finished product of the material in the requested

quantity and mixed thoroughly; if necessary, dilute and hold in accordance with the requirements for the material.

Ready-to-apply coating material shall be applied during a limited period of time in accordance with the material requirements.

7.6 Before usage, the coating material is brought to the working viscosity in accordance with the requirements for the material and filtered through the filter material.

8 Application and drying of coating materials

8.1 Basic parameters for the coating material application

8.1.1 The coating materials shall be applied after all of the surface preparations have been performed.

8.1.2 The following methods are used for applying coating materials:

- pneumatic spraying;
- hydraulic spraying;
- electrostatic spraying;
- dipping;
- brush coating.

8.1.3 The painting method of coating materials shall be chosen according to the normative documentation and also in accordance with the appearance, dimensions, the purpose of the product, and in accordance with the coating requirements.

8.1.4 Paint coating parameters shall be recorded in the process control log. The process control log shall include, but not limited to, the following:

- paint material name, part number, production lot number;
- expiration date;
- coated product name, part number, serial number;
- surface condition;
- mixing log;
- pot life;
- environment temperature, humidity;
- spray (compressed air) pressure;
- drying conditions (temperature, humidity, time);
- paint date.

8.2 Control during the coating process (operational inspection)

When applying each layer of the coating system (priming coat and functional coat), depending on the chosen method and application modes and taking into account regulatory requirements for the material, the following shall be controlled:

- surface quality (cleanliness, roughness) for painting according to [Clause 6](#);
- working viscosity of the material, depending on the method of application;
- distance to the surface to be painted and spray pressure (except for hand colouring);
- time between applying layers;
- drying modes (temperature, humidity, time);
- appearance;
- coating thickness.

8.3 Safety requirements and quality assurance

8.3.1 All work on the preparation, control and application of coating materials shall be carried out in rooms equipped with forced ventilation (local and general supply and exhaust) by qualified personnel using personal protective equipment, taking into account the requirements of local legislation.

8.3.2 Work shall be allowed to personnel who have passed a medical examination and instructed in safety in terms, training of work with coating materials, qualified (certification) and admitted to independent work.

8.3.3 Training and certification of qualified personnel shall be carried out in the company or in an accredited training organization. The training program shall be documented and typical workmanship standards in the form of acceptable and rejectable samples shall be available. Lists of approved operators shall be maintained.

8.3.4 The production personnel working with coating materials shall be provided with a set of special clothing and personal protective equipment:

- a) antistatic robes (used as a protection from the static-charge accumulation and as personal protection from the coating material contamination);
- b) safety footwear;
- c) rubber gloves (used for protecting a skin covering during coating material applying);
- d) knitted (lint-free) gloves (used for coating protection from dirt and grease on staff's hands)
- e) protective glasses (used as a protection for visual organs);
- f) respirators (used as protection for respiratory organs).

Production personnel shall be familiar with the risk data indicated in the safety data sheets for each coating material used in the coating process.

8.3.5 The safety of the process of preparation and application of coating materials is ensured by the maximum mechanization of all technological operations. The measuring tools should be calibrated.

8.3.6 Fire safety of works shall be ensured by the observance of the order of storage of fire hazardous materials and provision of production and auxiliary premises with fire extinguishing means.

8.3.7 In industrial and laboratory premises intended for surface preparation and coating material application, the temperature and humidity of the ambient environment shall correspond to the requirements stated in the normative documentation for the specific material. Equipment and personnel should be protected from static electricity.

8.3.8 All the electrical tools and equipment used in the area where flammable solvent vapour can exist shall be fire- and explosion-proof.

8.3.9 The areas for coating materials preparation and application shall be isolated from work locations, which are sources of contamination.

8.3.10 After working with coating materials, to avoid coating materials contamination on tools and equipment, all these tools and equipment shall be cleaned by using a special solvent, dried, and stored in their proper locations.

8.3.11 Solid and liquid waste left after the equipment and paint spray booth washing-out (polluted solvents, polluted and used rags) shall be collected into the special containers with tight-fitting lids.

8.3.12 After coating application, products are not allowed to be taken with unprotected hands; knitted (lint-free) gloves shall be used to avoid contamination of a painted surface.

8.4 Curing of coating

8.4.1 The painted product shall be placed in a clean, controlled environment for final curing.

8.4.2 The curing conditions of the coating depend on the requirements of the normative documentation for the coating material and the product to be painted.

9 Quality control of an applied coating

9.1 The quality control of the coating shall be performed on the product to evaluate the appearance and on test specimens for other parameters established for a particular coating.

9.2 Coating test specimens shall be made from the same material (batch) and with the same surface preparation as the product to be painting. The coating shall be applied to the test specimens simultaneously with the colouring of the product according to the same scheme, with the same paint and varnish material, for the same technological cycle. Test specimens shall be prepared in accordance with ISO 1514.

9.3 The result of inspection and tests of the coating shall be recorded in the report (protocol) on the test.

9.4 The quality of the applied coating should be evaluated by the test methods given in [Annex A](#). See [Table A.1](#).

9.5 The required parameters and test methods shall be used in accordance with the normative documentation for the specific coatings.

9.6 The appearance of the coating should be determined visually in diffused daylight or artificial lighting, while controlling the continuity of application, colour, gloss and its absence, and the presence of coating defects.

Visual inspection should be performed using reference samples that represent acceptable and defect sample respectively.

Possible types of defects are given in [Annex B](#). See [Table B.1](#).

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Annex A

(informative)

Test methods for the quality evaluation of the applied coating

Table A.1 — Parameters for controlling the quality of the applied coating

Name of parameter	Test method ^a
1 Main parameters	
1.1 Appearance	According to 9.6
1.2 Thickness	ISO 2808
1.3 Adhesion	ISO 2409 ISO 4624
1.4 Flow time (relative viscosity)	ISO 2431
1.5 A mass fraction of non-volatile substances	ISO 3251
2 Additional parameters	
2.1 Colour of a film	ISO 3668
2.2 Drying time and a degree of drying	ISO 9117-6
2.3 A degree of grinding	ISO 1524
2.4 Hiding power	ISO 28199-3 ISO 6504-1
2.5 Flexural elasticity of the film	ISO 1519
2.6 Durability of film on impact	ISO 6272-2
2.7 Hardness	ISO 1522
3 Specific parameters	
3.1 Solar absorptance α_s	ISO 16378
3.2 Emittance ϵ	
3.3 Electrical volume resistivity ρ	ISO 15091
3.4 Electrical surface resistance R	ASTM D257-14
3.5 Outgassing (TML, CVCM)	ASTM E595 ECSS-Q-ST-70-02C
3.6 UV resistance	ECSS-Q-ST-70-06C ASTM E512
3.7 Radiation resistance	ISO 15856
3.8 Atomic oxygen resistance	ASTM E2089
3.9 Thermal cycling	ECSS-Q-ST-70-04C
3.10 Gloss	ISO 2813
NOTE 1: Additional and specific parameters are controlled when indicated in the normative documentation for a specific coating.	
NOTE 2: This list is not exhaustive.	
^a Test methods of equivalent national standards may be used.	