INTERNATIONAL STANDARD

ISO 16691

First edition
2014-02-15

Space systems — Thermal control coatings for spacecraft — General requirements

Systèmes spatial — Revetements pour le contrôle thermique des satellites et vehicules spatiaux — Exigences générales

Reference number
ISO 16691:2014(E)

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Published in Switzerland

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Foreword

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The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This International Standard explains technical information for TCCs selection and application required to confirm their compliance with the requirements of the thermal control for spacecraft.

This International Standard classifies thermal control coatings in accordance with their usage in passive and/or active thermal control subsystems for reduction of external heat absorption or regulation of radiant heat exchange between on-board equipment on spacecraft, their general properties, and their special characteristics for space environment applications.

This International Standard also contains special recommendations for surface preparation, application of coating systems and curing, and establishes requirements for test methods on estimating properties of thermal control coatings according to their target use.

Space systems — Thermal control coatings for spacecraft — General requirements

1 Scope

This International Standard defines general requirements for thermal control coatings (TCC) that are applied on metallic and/or non-metallic surfaces of spacecraft and payloads in order to provide the following thermo-optical properties:

— α_S: solar absorptance;

— ε: emittance.

The function of TCC is to reduce external heat absorption and/or to regulate radiant heat exchange between on-board equipment on spacecraft.

2 Normative references

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

ISO 9117-1:2009, *Paints and varnishes — Drying tests — Part 1: Determination of through-dry state and through-dry time*

ISO 14624-3, *Space systems — Safety and compatibility of materials — Part 3: Determination of offgassed products from materials and assembled articles*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

3.1.1
active thermal control system
system where the active thermal control method is used

Note 1 to entry: The active thermal control method is the procedure to control the temperature using mechanical mobile components or fluid, using electric energy from a heater, changing the component's thermo-physical property, or utilizing another technology to change/control the temperature.

[SOURCE: JERG-2–310:2009]

3.1.2
coating
continuous layer formed from a single or multiple application of a coating material to a substrate

[SOURCE: ISO 4618:2006]

3.1.3
coating material
product in liquid, paste, or powder form, that, when applied to a substrate, forms a film possessing protective and/or other specific properties

[SOURCE: ISO 4618:2006]

3.1.4
coating process
process of application of a coating material to a substrate, such as dipping, spraying, roller coating, brushing

[SOURCE: ISO 4618:2006]

3.1.5
coating system
combination of all coats of coating materials which are to be applied or which have been applied to a substrate

[SOURCE: ISO 4618:2006]

3.1.6
emissivity
emittance
ε

$$\varepsilon = M/Mb$$

where M is the radiant exitance of a thermal radiator, and Mb is the radiant exitance of a blackbody at the same temperature

Note 1 to entry: The following adjectives should be added to define the conditions:

— **Total**: If they are related to the entire spectrum of thermal radiation (this designation can be considered as implicit);[7]

— **Spectral or monochromatic**: If they are related to a spectral interval centered on the wavelength λ;[7]

— **Hemispherical**: If they are related to all directions along which a surface element can emit or receive radiation;[7]

— **Directional**: If they are related to the directions of propagation defined by a solid angle around the defined direction;[7]

— **Normal**: If they are related to the normal direction of propagation or incidence to the surface.[7]

[SOURCE: ISO 80000-7:2008]

[SOURCE: ISO 16378]

3.1.7
paint
pigmented coating material which, when applied to a substrate, generally forms an opaque film having protective or specific technical properties

[SOURCE: ISO 4618:2006]

3.1.8
paint film
intact coating that is formed by applying one or multiple layers of coating materials on a substrate

3.1.9
passive thermal control system
system where the passive thermal control method is used

Note 1 to entry: The passive thermal control method is the procedure to control the temperature of the component within the specified range by adjusting the paths of conduction and radiation, and by the selection of geometric form of each surface and thermo-physical property of the spacecraft.

[SOURCE: JERG-2–310:2009]

3.1.10
payload
set of space segment elements (parts of a space system placed in space to fulfill the space mission objectives)

Note 1 to entry: A spacecraft payload is a set of instruments or equipment that performs the user mission.

Note 2 to entry: A launcher payload is a set of space segment elements carried into space in accordance with agreed position, time, and environmental conditions.

[SOURCE: ISO 10795:2011]

3.1.11
primer
paint that has been formulated for use as a priming coat on prepared surfaces

3.1.12
priming coat
first coat of a coating system

3.1.13
solar absorptance
α_S
ratio of the solar radiant flux absorbed by a material (or body) to the radiant flux of the incident radiation

3.1.14
substrate
surface to which a coating material is applied or is to be applied

3.1.15
thermal control coating
TCC
coating 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

3.1.16
varnish
clear coating material which, when applied to a substrate, forms a transparent film

3.1.17
witness sample
sample pieces that represent the coated product

Note 1 to entry: They shall be made in the form of the flat plates using the same coating material with the product, and coated simultaneously. Used for destructive test and test that requires limited size of specimen.

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this International Standard.

BOL beginning of life

EMC electromagnetic compatibility

EOL end-of-life

ESD electrostatic discharge

TCC(s) thermal control coating(s)

TCS(s) thermal control (sub) system(s)

QA quality assurance

UV ultraviolet

VUV vacuum ultraviolet

4 General

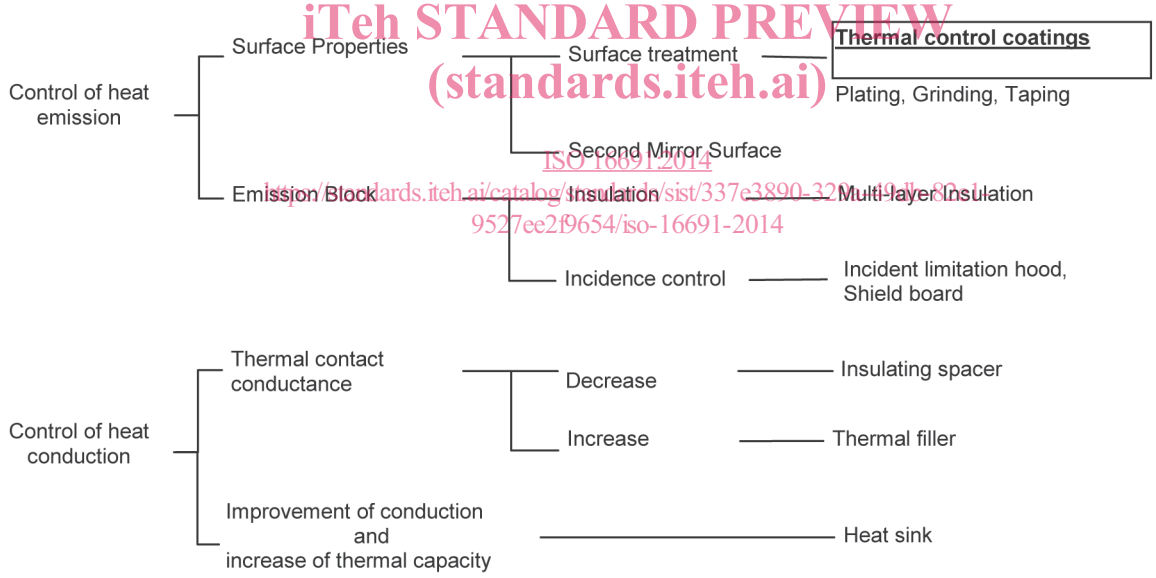

Figure 1 — The mapping of thermal control coatings relative to each passive thermal control material

The action of the space environment strongly depends on the spacecraft service conditions. These are defined by the orbits where spacecraft are intended to operate.

Heat sources which determine the temperature of a spacecraft are mainly solar rays and earth albedo. The quantity of heat emitted from a spacecraft is equal to the sum of heat input and the quantity of internal heat produced from the all equipment of a spacecraft.

Nevertheless, there are general factors that exert influence on spacecraft serviceability and efficiency: vacuum, electromagnetic solar radiation, including UV-radiation and VUV-radiation, ionizing radiations, atomic oxygen, temperature, contamination, micrometeoroids, and debris environment effects.

When in service, undesirable effects can occur, such as electrostatic charging, generation of spacecraft outer atmosphere, and alternating thermal loads.

TCC are generally damaged by UV and charged particle exposure. In addition, at altitudes of roughly 200 km-600 km erosion of some TCC can occur due to atomic oxygen. Bleaching or whitening of UV/charged particle induced damage of these coatings can also occur from atomic oxygen exposure.

TCCs are the elements of passive and/or active TCSs for temperature regulation of spacecraft. The location of thermal control coatings in relation to other passive thermal control materials is shown in Figure 1 above.

TCCs are applied on spacecraft surfaces, individual units, assemblies, and devices that are to be temperature-controlled. They are used to maintain the preset temperature conditions of a spacecraft by establishing the balance between the heat absorbed from an environment and/or emitted by on-board sources, the energy redistributed between equipment and spacecraft structure, and the energy radiated in environment.

The thermo-optical properties of a TCC are used in TCSs design. TCC shall meet the specification requirements at the BOL and maintain required properties at the EOL of the spacecraft.

EMC/ESD, ageing, difference of properties between the beginning and the end of service life are defined by service conditions and purposes of spacecraft. These properties are measured when candidate TCC materials are under consideration for a TCS in the design stage.

The scope depends on the coating to be tested and requirements of designer and/ or production engineer.

4.1 Functionality

With regard to their functionality, determined by the coating's ability to absorb or reflect the radiant energy, the thermal control coatings can be classified as follows:

— **I:** true absorber ($\alpha_s \rightarrow 1, \varepsilon \rightarrow 1$);

— **II:** solar reflector ($\alpha_s \rightarrow 0, \varepsilon \rightarrow 1$);

— **III:** solar absorber ($\alpha_s \rightarrow 1, \varepsilon \rightarrow 0$);

— **IV:** true reflector ($\alpha_s \rightarrow 0, \varepsilon \rightarrow 0$).

4.1.1 Class I

Class I (black) TCCs absorb the heat from higher temperature objects and transmit the heat to lower temperature one, and promote intensification of the radiant heat transfer between surfaces of devices and units, as well as between devices, units, and environment.

Black TCCs are mainly applied to inner surfaces. They are applied on surfaces of spacecraft optical devices (radiation-measuring instruments, analog of an ideal radiator), on lens cells, blends, and barrels of optical devices (cameras, telescopes, scanners of a terrestrial surface), and on external surfaces to absorb radiation from the sun. Additionally, these coatings prevent the reflection of light from one surface to another.

4.1.2 Class II

Class II (white) TCCs reflect incident light and thermal radiation from heat sources such as solar rays and earth albedo to maintain the temperature of spacecraft design components within the working range and increase efficiency of TCSs.

White TCCs are mainly applied to outer surfaces. Class II TCCs can also be used to sink heat in environments to lower temperature of spacecraft members.