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Space product assurance

Measurements of thermo-optical properties of thermal control materials

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Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS Executive Secretariat, endorsed by the Document and Discipline Focal points, and approved by the ECSS Technical Authority.

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Change log

ECSS-Q-70-09A 29 August 2003	First issue Transforming ESA-PSS-01-709 into an ECSS Standard
ECSS-Q-70-09B	Never issued
ECSS-Q-ST-70-09C 31 July 2008	Second issue Redrafting of ECSS-Q-70-09A according to ECSS drafting rules and new template. In particular: • The content of the original section 4 was moved to the section 4.1. • The content of the original section 6 was moved to the section 4.3. • The content of the original section 7 was moved to the sections 4.4. • The content of the original section 5 was moved to the informative Annex C and referenced in the section 4.2. • A DRD for evaluation reports records was created in the normative Annex A. • A DRD for audit / review reports records was created in the normative Annex B.

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Introduction

The thermo-optical properties of materials are of importance to enable the calculation of the thermal housekeeping and radiative heat transfer.

This Standard describes the methodology, instruments, equipment and samples, used to calculate the thermo-optical properties of thermal-control materials, i.e. solar absorptance [α_s or α_p] and the infrared emittance [ε_h or ε_n].

In general this procedure has been written in connection with instruments and equipment available at ONERA, INTESPACE and ESTEC; however, any supplier is encouraged to built up his own instrument or equipment provided the accuracy of the results is equivalent to the one specified herein.

In this Standard, the supplier is identified as the entity that performs the test.

1 Scope

This Standard describes the methodology, instruments, equipment and samples, used to calculate the thermo-optical properties of thermal-control materials.

The following test methods are detailed in this Standard including the configuration of samples and calculations:

- Solar absorptance using spectrometer (α_s) - (see Annex C.2).
- Comparative test method (α_p) - (see Annex C.3).
- Infrared emittance using thermal test method (ε_h) - (see Annex C.4).
- Infrared emittance using IR spectrometer (ε_h) - (see annex C.5).
- Infrared emittance using portable equipment (ε_n) - (see Annex C.6).

This standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system – Glossary of terms
ECSS-Q-ST-10	Space product assurance – Product assurance management
ECSS-Q-ST-10-09	Space product assurance – Nonconformance control system
ECSS-Q-ST-20-07	Space product assurance – Quality assurance for test centres
ECSS-Q-ST-70-02	Space product assurance – Thermal vacuum outgassing test for the screening of space materials

3 Terms, definitions and abbreviated terms

3.1 Terms defined in other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.

3.2 Terms specific to the present standard

3.2.1 absorptance

ratio of the intensity of the incident light to the transmitted or reflected light

3.2.2 emittance (ε)

ratio of the radiant intensity of the specimen to that emitted by a black body radiator at the same temperature and under the same geometric and wavelength conditions

NOTE For example:

- Hemispherical emittance (ε_h) - conditions for incident or viewing of flux over a hemispherical region.
- Normal emittance (ε_n) - conditions for incidence or viewing through a solid angle normal to the specimen.

3.2.3 solar absorptance (α)

ratio of the solar radiant flux absorbed by a material (or body) to that incident upon it

NOTE Differentiation is made between two methods:

- Spectroscopic method using a photospectrometer covering the range from 0,25 μm up to 2,5 μm for the determination of α_s.
- Portable equipment using a xenon flash for relative measurements (α_p).

3.3 Abbreviated terms

The abbreviated terms defined in ECSS-S-ST-00-01 apply.

4 Requirements

4.1 Preparatory conditions

4.1.1 Hazards, health and safety precautions

a. For "Safety and security" ECSS-Q-ST-20-07C shall apply.

NOTE For example, for hazard and health (safety) and for access control (security).

4.1.2 Preparation of samples

4.1.2.1 Configuration

a. The supplier shall prepare the material samples according to the process specification or manufacturer's data.

b. The material shall be representative of batch variance.

NOTE For example: the application procedure for paint can result in different thermo-optical properties, depending on the painter and the type of spray gun used. This is the reason why the samples are coated or made at the same time as the workpiece.

4.1.2.2 Cleaning

a. Cleaning method and other treatment of the sample shall be the same (and not more) as for the flight hardware.

NOTE In particular, solar absorptance properties are very sensitive to contamination and if the sample or the flight hardware is contaminated (even by hand grease), the test results are completely erroneous.

4.1.2.3 Handling and storage

a. The supplier shall handle the samples with clean nylon or lint-free gloves.

b. The supplier shall store the samples in a cleanliness-controlled area, with a room temperature of (20 ± 3) °C and relative humidity of (55 ± 10) %.

c. The supplier shall shield coated surfaces from contact by using polyethylene or polypropylene bags or sheets.

d. The supplier shall avoid mechanical damage of the sample by packing the polyethylene or polypropylene-wrapped workpieces in clean, dust- and lint-free material.

e. The supplier shall label limited-life materials with their relative shelf lives and dates of manufacture.

4.1.2.4 Identification

a. The supplier shall use a completed "Material identification card" in conformance with DRD in ECSS-Q-ST-70-02 for samples submitted for testing.

b. The supplier shall verify the existence of a safety data sheet for hazardous samples

NOTE The safety data sheet is a set of information provided by the supplier of the chemical substance.

4.1.3 Facilities

4.1.3.1 Cleanliness

a. The supplier shall keep the work area clean and free of dust.

b. The supplier shall use filters for the air used for ventilation.

NOTE This is to prevent contamination of the sample.

4.1.3.2 Environmental conditions

a. The ambient conditions for the process and work areas shall be (22 ± 3) °C with a relative humidity of (55 ± 10) % unless otherwise stated.

4.1.3.3 Equipment

a. The supplier shall define the equipment in the test procedure.

4.2 Selection of test methods

a. The supplier shall select one or more of the following test methods depending on the type and size of the samples:

1. Solar absorptance using spectrometer (α_s),

   NOTE For details and conditions for the samples see Annex C.2.

2. Comparative test method (α_p),

   NOTE For details and conditions for the samples see Annex C.3.

3. Infrared emittance using thermal test methods (ε_h),

   NOTE For details and conditions for the samples see Annex C.4.

4. Infrared emittance using IR spectrometer (ε_h),

   NOTE For details and conditions for the samples see Annex C.5.

5. Infrared emittance using portable equipment (ε_n).

   NOTE For details and conditions for the samples see Annex C.6.

4.3 Quality assurance

4.3.1 Data

a. The supplier shall retain the quality records for ten years or in accordance with project contract requirements.

   NOTE Example of quality records are log sheets.

b. An evaluation report shall be produced in conformance with Annex A and is a quality record

4.3.2 Calibration

a. The supplier shall calibrate any measuring equipment to traceable reference standards.

b. The supplier shall record any suspected or actual equipment failure as a project nonconformance report in conformance with NCR DRD in ECSS-Q-ST-10-09.

   NOTE This is to ensure that previous results can be examined to ascertain whether or not reinspection and retesting is necessary.

4.4 Audit of measurement equipment

4.4.1 General

a. The customer shall perform the standard audit according to ECSS-Q-ST-10.

   NOTE 1 The main purpose of a standard audit is to ensure the validity of test results by comparison of the test data on identical materials by different test houses.

   NOTE 2 The thermo-optical property data from test houses for the projects of the customer, obtained in the manner laid down in this Standard, are only accepted for the projects of the customer if the test house is certified to perform the relevant procedure in this Standard.

4.4.2 Audit of the system (acceptance)

a. The customer's product assurance department shall audit the system after it has been built or purchased.

NOTE The audit is necessary before the system can be accepted for running qualification or quality control tests on materials for use in customer projects.

b. The customer shall establish an audit report in conformance with Annex B.

c. The customer shall issue the certificate of conformance after a successful audit or renew it every three years after a successful audit.

4.4.3 Annual regular review (maintenance) of the system

a. The supplier shall establish an annual regular review report in conformance with Annex B.

b. For each nonconformance the supplier shall perform the following actions:

1. determine the reasons for the nonconformance, and
2. perform a further test in accordance with clause 4.4.2.

NOTE These actions are necessary before a certificate of conformance is renewed.

c. The supplier shall deliver the review report to all customers within six weeks after the end of the regular review or evaluation testing.

4.4.4 Special review

a. The supplier shall report all modifications of the apparatus or associated equipment.

b. The customer shall audit the modifications, if deemed necessary, before utilization of the modified system for the customer's project.

c. For major modifications the supplier shall retest the apparatus as described in clause 4.4.2.

Annex A(normative) Evaluation report of the measurement of thermo-optical properties of thermal control materials– DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-09, requirement 4.3.1b.

A.1.2 Purpose and objective

The purpose of the document is to describe the contents of the evaluation report of the measurement of thermo-optical properties of thermal control materials.

A.2 Expected response

A.2.1 Scope and content

a. The report shall contain the trade names and batch numbers of the materials under test.

b. The report shall contain the name of the supplier through whom the purchase was made.

c. The report shall contain the summary of the preparation and conditioning schedule.

NOTE E.g. mixing proportions, coating thickness, cure time and temperature, post-cure, cleaning procedure.

d. The report shall contain the test method description and calibration.

e. The report shall contain any noticeable incident observed during the measurement.

f. The report shall contain the deduced results.

A.2.2 Special remaks

None.

Annex B (normative) Audit / review report for the measurement equipment of thermo-optical properties of thermal control materials - DRD

B.1 DRD identification

B.1.1 Requirement identification and source document

This DRD is called from ECSS-Q-ST-70-09, requirements 4.4.2b and 4.4.3a

B.1.2 Purpose and objective

The purpose of the document is to describe the contents of the audit and review report for the measurement equipment of thermo-optical properties of thermal control materials.

B.2 Expected response

B.2.1 Scope and contents

a. The audit / review report shall describe the inspection of the apparatus and associated equipment.

b. The audit report shall describe the test on a defined set of materials.

c. The review report shall describe the mutual comparability evaluation (testing).

d. The audit / review report shall contain the nonconformances.

e. The audit / review report shall contain the audit findings.

B.2.2 Special remarks

None.

Annex C (informative) Test methods

C.1 Format

The format of each clause of the present annex is as follows:

C.x.1 General

C.x.2 Configuration of samples

C.x.3 Test apparatus and setting up

C.x.4 Test process and measurement

C.x.5 Calculations

C.2 Solar absorptance using spectrometer (α_s)

C.2.1 General

Solar absorptance is calculated using the absorption spectrum of the material over the region from 0,25 μm to 2,5 μm and this spectrum is then multiplied with the solar spectrum. The absorption spectrum should be measured using an integrating sphere. For absolute measurements a sphere with central sample mounting should be used.

A sphere with a sample holder on the sidewall can also be used. In this case the reflectivity is compared to a known standard (e.g. calibrated Al-mirror or calibrated Spectralon® standard).

C.2.2 Configuration of samples

Typical dimensions of the sample are 15 mm × 15 mm to 25 mm × 25 mm. Depending on the method and equipment used, these dimensions can vary.

Flexible samples should be mounted on a rigid surface. Measurements are only valid on flat samples. However, it is possible to perform measurements on spherical curved samples provided the radius of curvature exceeds 300 mm.

C.2.3 Test apparatus and setting up

The test apparatus consists of a spectrometer, covering the range from 0,25 μm to 2,5 μm. The following are recommendations for the test apparatus and setting up:

a. The wavelength resolution of the spectrometer should be compatible with the resolution used for the solar spectrum.

b. The signal to noise ratio should be better than:

    1. ±1 % full scale in the region between 250 nm and 2 000 nm;

    2. 5 % full scale in the region between 2 000 nm and 2 500 nm.

c. The associated sphere should have a maximum port to total surface ratio of 5 %.

    NOTE 1 If the test apparatus is used in a central sample mode, i.e. an "Edwards"-type integrating sphere, the measurement is called "absolute".

    NOTE 2 If the sample is mounted on the sidewall, the measurement is done towards a calibrated standard that can be specular (e.g. Al-mirror) or diffuse (e.g. Spectralon®).

d. The responsible test officer should make the choice of a standard based on the visual aspect of the sample.

e. For materials having, in the visible region, a large specular component, a standard mirror should be used.

f. When the diffuse component is predominant in the visible region, a diffuse Spectralon® sample should be used.

g. The standard used for the measurement should be indicated in the report.

C.2.4 Test process and measurement

Before starting a measurement sequence the 100 % and 0 % baseline should be taken (using the standard reference as applicable). The baseline should be measured at least once a day when equipment is switched on.

C.2.5 Calculation of absorptance

The spectrum is taken between 250 nm and 2 500 nm, and covers 96 % of the total energy.

$$\alpha_s = 1 - R_s$$

$$R_S = \frac{\int_{\lambda_1}^{\lambda_2} R(\lambda) S(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} S(\lambda) d\lambda}$$

where:

$R(\lambda)$ is the spectral reflectance after 100 % reference correction;

$S(\lambda)$ is the spectral solar irradiance (see ASTM E 490);

$d\lambda$ is typically 1 nm;

λ_1 is 0,25 μm;

λ_2 is 2,5 μm.

For transparent test pieces it is possible to calculate the absorptance by the same method, because:

$$\alpha(\lambda)=1-[R(\lambda)+T(\lambda)]$$

It is also possible to calculate absorptance for a spectrum other than the solar spectrum, e.g. for solar simulators.

C.3 Comparative test method (α_p)

C.3.1 General

This method is based on comparing the reflection of a Xenon flash by a known appropriate reference material to the reflection of an unknown sample. The nature of the reference material (chemical composition and surface morphology) should be representative for the unknown. The solar absorption of the reference surface should be measured using the method described in C.2.

This method has limitations due to the fact that the flasher spectrum is not identical to the solar spectrum.

Special precautions should be taken when using portable reflectometer equipment.

This equipment should only be used for comparative measurements. It should be used in conjunction with known reference or calibrated materials, identical to or at least having similar optical behaviour to the material to be measured. If such an approach is followed, the equipment should give a direct and correct result within the linearity limitation. If the reference used is not identical to the material under test, the result of the reading not only depends on the linearity of the equipment but also on the spectral reflectivity of the material. Any reporting of results should include the detailed test conditions.

C.3.2 Configuration of samples

The minimal sample dimensions are dictated by the diameter of the aperture on the portable equipment. This diameter is typically between 15 mm and 20 mm.

Measurements are only valid on flat samples. However, it is possible to perform measurements on spherical curved samples, provided the radius of curvature exceeds 300 mm.

C.3.3 Test apparatus and setting up

The equipment consists of a flasher, able to produce a flash with a reproducible spectrum. The total intensity and the reflected intensity of the flasher are measured both with the reference surface and the test surfaces.

C.3.4 Test process and measurement

a. Before any measurement is performed the equipment should be stabilized following the instructions given by the manufacturer.

b. The equipment should be calibrated following the instructions given by the manufacturer.

c. The calibration should, as a minimum, include a "zero" or baseline measurement as well as the measurement of the reference material.

d. After calibration with the appropriate reference material, the unknown sample should be measured.

e. If several materials have to be measured, calibration should be repeated at regular time intervals, depending on the known stability of the equipment.

f. For statistical reasons each measurement should be repeated at least 5 times; the average and standard deviation of the measurements should be calculated and reported.

g. Some equipment makes these calculations automatically through integrated software. The standard deviation between measurements should be 0,02 or better.

C.3.5 Calculations

- Reflectivity reference surface (R_r):

$$R_r = I_r / I_{tr}$$

where:

I_r is the intensity of flash reflected on reference surface;

I_{tr} is the total intensity of flash during reference flashing.

- Reflectivity sample surface (R_s):

$$R_s = I_s / I_{tr}$$

where:

I_s is the intensity of flash reflected on sample surface;

I_{ts} is the total intensity of flash during sample flashing.

$$R = I_s / I_r \times R_r$$

where:

R_r is the measured reference reflectivity (using method C.2);

R is the calculated sample reflectivity.

$$\alpha_p = 1 - R$$

C.4 Infrared emittance using thermal test method (ε_h)

C.4.1 General

By means of the dynamic thermal method, one can determine the total hemispherical emittance from the decrease in temperature of a test item with well-defined thermal characteristics.

C.4.2 Configuration of samples

A “standard sample substrate” as detailed in Figure C- 1 should be used in favour of any other geometrical shape.

In particular, the sample should be made by machining and not by cutting out with shears since this flattens the edges and does not produce a very accurate square shape.

C.4.3 Test apparatus and setting up

For the dynamic thermal method, it is assumed that the specific heat of the test piece is known. A lightweight test piece (i.e. one with a low heat capacity) is bonded by means of double-sided adhesive tape to a gold-plated substrate (standard sample substrate) the heat capacity of which is high with respect to that of the test piece.

Initially, the gold-plated substrate’s emittance is measured. A copper-Constantan® thermocouple is fixed in the centre of the gold-plated substrate. Four nylon threads (e.g. ∅ = 0,16 mm) secure the substrate and test piece to the centre of a sample holder which is fixed on the axis.

This is then lowered to the centre of the cryogenic shroud, which is coated in black and cooled with liquid nitrogen.

The dimensions are such that the shroud area is more than 100 times the total area of the test piece.

A window made of Suprasil® quartz (working diameter: 90 mm) enables this test piece to be illuminated by an external heat source.

C.4.4 Test process and measurement

After a sufficient vacuum is attained (< 10^{-6} hPa), and the temperatures of the shroud and sample holder are stabilized, the test piece is heated up to 30 °C. The decreasing temperature is then recorded down to 20 °C. The total hemispherical temperature is then calculated for a temperature of 25 °C. It is possible to do this for any temperature between -50 °C and +75 °C by using a similar method.

NOTE The errors of measurement depend mainly on the following quantities:

- specific heat of the test piece: C_e
- temperature: T

- time: t

The first quantity, C_e, can be measured from the test piece by means of thermal analyses such as with a differential scanning calorimeter, or is taken from the literature for clearly defined materials.

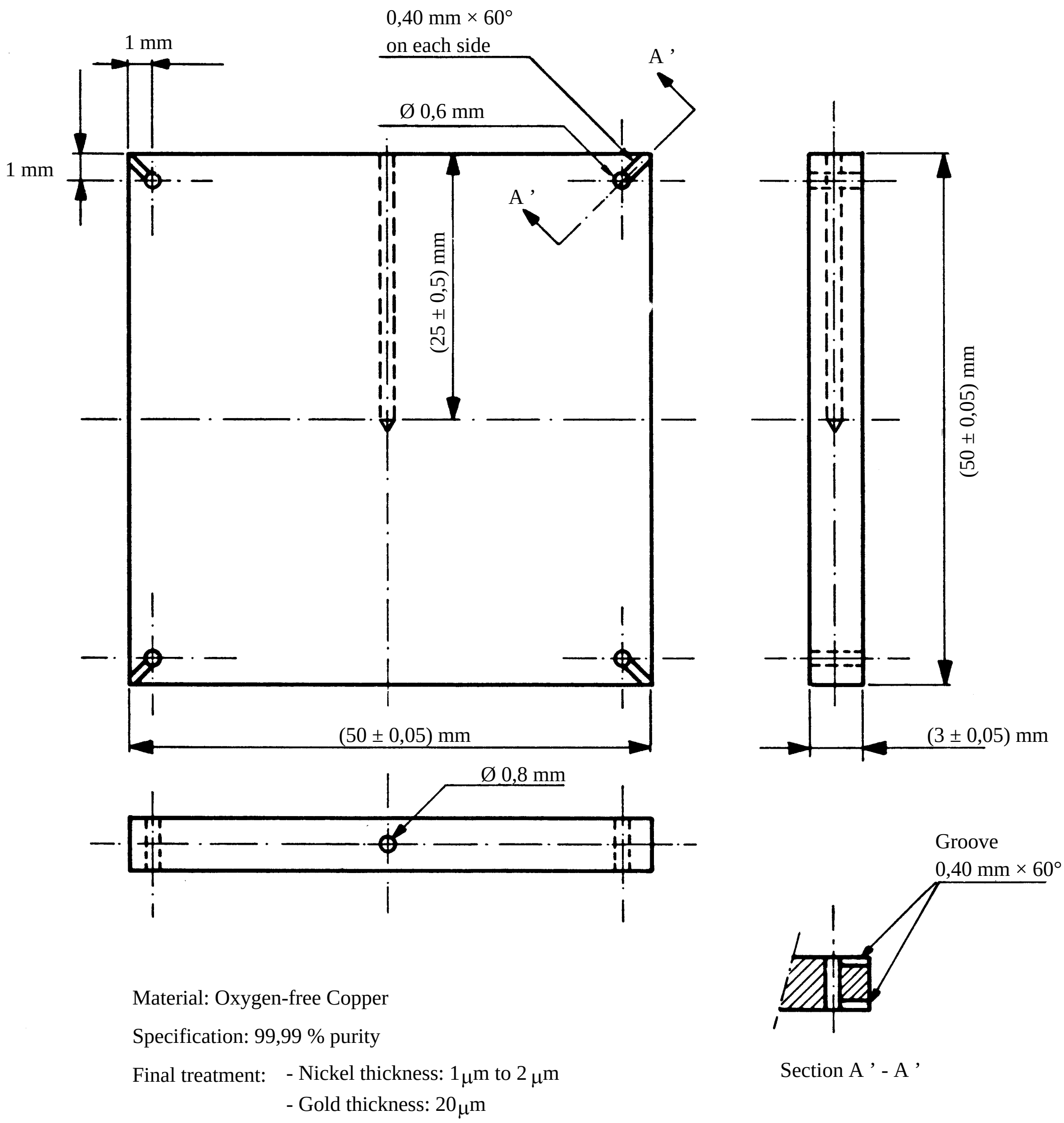

Figure C- 1: Standard sample substrate

C.4.5 Calculations of total hemispherical emittance

Calculation of the emittance is performed using the following formulas:

$$\varepsilon = \frac{(M_r C_r)_0 + (M_e C_e)_{Tmoy}}{4\sigma S T_0^3 (t_2 - t_1)} [(\alpha T_0) \ln A + \ln B + 2C]$$

$$A = \frac{(T_2^2 + T_0^2)(T_1^2 - T_0^2)}{(T_2^2 - T_0^2)(T_1^2 + T_0^2)}$$

$$B = \frac{(T_2 + T_0)(T_1 - T_0)}{(T_2 - T_0)(T_1 + T_0)}$$

$$C = (1 - \beta T_0^2)\left(\arctan\frac{T_2}{T_1} - \arctan\frac{T_2}{T_0} \right)$$

$$\varepsilon_c = \frac{\varepsilon S - \varepsilon_r S_r}{S_c}$$

where:

— (t_1, T_1) and (t_2, T_2) are two points on a cooling curve at times t_1 and t_2 for which the corresponding temperatures are T_1 and T_2;

— (MC) is the total heat capacity of a test piece with gold-plated substrate.

If the variation of specific heat is assumed to be parabolic with the temperature, then:

$$(MC)_T = M_r C_r + M_e C_e$$

and

$$(M_r C_r)_T = (M_r C_r)_0 (1 + \alpha T + \beta T^2)$$

where:

ε	is the total hemispherical emittance of test piece plus substrate;
ε_r	is the total hemispherical emittance of the gold-plated substrate;
ε_e	is the total hemispherical emittance of the test piece;
$(M_r C_r)_0$	is the thermal mass of the substrate at 0 °C (JK^{-1});
M_r	is the weight of gold-plated piece (kg);
C_r	is the specific heat of gold-plated piece (J kg K^{-1});
M_e	is the weight of the test piece (kg);
C_e	is the specific heat of the test piece (J kg K^{-1});
S_r	is the gold-plated surface area (m^2);
S_e	is the surface area of the test piece (m^2);
S	is the total emitting surface area, i.e. $S = S_e + S_r$ (m^2);
T_0	is the temperature of the cryogenic shroud (K);
t	is time (s);
σ	is the Stefan-Boltzmann constant = 5,7 × 10^{-8} W m^{-2} K^{-4}.

C.5 Infrared emittance using IR spectrometer (ε_h)

C.5.1 General

This method is based on optical measurements of absorptance of materials in the infrared range from 3 µm to 21 µm. This absorptance is determined measuring total hemispherical reflectance of these materials using an integrating sphere coupled with an infrared spectrometer.

As for solar absorptance measurements, one can make absolute measurements with a central sample holder, but another solution is to measure the reflectivity of the sample on the wall comparing the reflectivity of the sample with a calibrated standard (mirror or Infragold®). The spectrum obtained is weighted by blackbody spectrum and integrated.

C.5.2 Configuration of samples

The size of the samples depends on the configuration adopted (either central or tangential) and the sizes of the sphere, of the beam, of the sample holder and of the measurement port. The sample should be large enough to receive the complete incident beam but small enough to disturb, at the minimum, the sphere integrity.

A classical size is 20 mm × 20 mm or 20 mm diameter for an integrating sphere of 150 mm in diameter with a central sample mounting, with a maximum thickness of 5 mm.

The samples should be rigid.

C.5.3 Test apparatus and setting up

The test apparatus consists of a IR reflectometer covering the range from 3 µm to 21 µm equipped with an integrating sphere. The range of measurement is limited by the material used for the sphere walls (Infragold®).

a. The spectrometer should be purged with a permanent dry air flux in order to eliminate CO_2 and H_2O absorption bands.

b. The signal to noise ratio over the whole interval from 2,5 µm to 20 µm should be better than 1 % full scale.

C.5.4 Test process and measurement

The measurement on the sample is made after a baseline measurement is obtained either on the standard sample for a tangential sample, or on the wall sphere if the sample is centrally mounted.

The baseline and the sample measurement should be made in the same conditions of the purge of the spectrometer.

C.5.5 Calculation of emittance

The spectrum obtained by the above test method is then weighted and integrating following the formula:

$$\varepsilon = \frac{\int_{3\mu m}^{20\mu m} A(\lambda)E(\lambda)d\lambda}{\int_{3\mu m}^{20\mu m} E(\lambda)d\lambda}$$

where:

— $A(\lambda)$ is the spectral absorptance of the sample after 100 % reference correction ($A(\lambda) = 1 - R(\lambda)$ or $A(\lambda) = 1 - (R(\lambda) + T(\lambda))$ if the sample is transparent);

— $E(\lambda)$ is the blackbody emittance spectrum at 300 K and can be calculated with the Planck law;

$$E(\lambda) = \frac{2\pi hc^2\lambda^{-5}}{e^{hc/\lambda kT} - 1}\left(W/m^2\mu m\right);$$

— $h = 6{,}626 \times 10^{-34}$ Js and $k = 1{,}381 \times 10^{-23}$ JK^{-1}.

The emittance at other temperatures can also be determined with measurements in another wavelength range. In this case, the blackbody spectrum should be calculated at this new temperature.

C.6 Infrared emittance using portable equipment (ε_n)

C.6.1 General

This method is used to cover determination of the total normal emittance of opaque surfaces when using portable reflectometer instruments.

This test method is suitable for measuring over large surfaces where a non-destructive test is desired.

Depending on the equipment, the signal obtained is integrated over a defined spectral range (e.g. the “Gier Dunkle” DB-100 equipment is an infrared reflectometer and has an integration from 5 µm to 25 µm).

C.6.2 Configuration of samples

The minimal sample dimensions are dictated by the diameter of the aperture on the portable equipment. This diameter is typically between 15 mm and 20 mm.

Measurements are only valid on flat samples. However, it is possible to perform measurements on spherical curved samples, provided the radius of curvature exceeds 300 mm.

C.6.3 Test apparatus and setting up

The surface to be measured is placed against an aperture on the portable sensing component. The specimen is alternately irradiated with infrared radiation from two heat sources, one at near ambient and the other at a slightly elevated temperature.

The detector receives both the radiation emitted from the test specimen and a constant radiation of all other surfaces inside the optical path. Only the reflected energy from the test specimen varies with the alternating irradiation and the detection amplifying system is made to respond only to this modulated signal.

The instrument should be calibrated with standards of known emittance.

C.6.4 Test process and measurement

The measurement on the sample is made after calibrating the instrument with known reflectance standards.

The calibration should be performed on at least two reference samples having low (black) and high (gold) reflectance properties and verified periodically by re-measuring the standards.

For semi-transparent samples, a correction should be made for transmittance losses. Another possibility is to cover the semi-transparent sample with an opaque material from behind. In this case, the reflectance of this combination can be measured.

C.6.5 Calculation of the normal emittance

The normal emittance for opaque material is defined as:

$$\varepsilon_N = 1 - R_s \tag{C-1}$$

$$I_D = R_S \sigma T_{IR}^{\ 4} \tag{C-2}$$

where:

ε_N is the normal emittance;

R_S is the sample reflectance;

σ is the Stefan-Boltzmann constant;

T_{IR} is the infrared source temperature;

I_D is the energy seen by the detector.

By keeping the infrared source at a fixed temperature, the terms σ and T_{IR} become constant:

$$K = \sigma T_{IR}^{\ 4} \tag{C-3}$$

with (C-2) and (C-3):

$$I_D = R_S K \tag{C-4}$$

The sample reflectance R_S is proportional to the measured signal I_D. The normal emittance can be obtained by subtracting the measured reflectance from unity.

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ASTM E 490	Standard Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables