**SLOVENSKI STANDARD**
**SIST EN 14607-1:2005**

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**Vesoljska tehnika – Mehanika – 1. del: Nadzor toplote**

Space engineering - Mechanical - Part 1: Thermal control

Raumfahrttechnik - Mechanik - Teil 1: Thermalkontrolle

Ingénierie spatiale - Mécanique - Partie 1: Contrôle thermique



**Ta slovenski standard je istoveten z: EN 14607-1:2004**



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**ICS:**

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| 49.140 | Vesoljski sistemi in operacije | Space systems and operations |

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EUROPEAN STANDARD
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# Space engineering - Mechanical - Part 1: Thermal control

Ingénierie spatiale - Mécanique - Partie 1: Contrôle thermique

Raumfahrttechnik - Mechanik - Teil 1: Thermalkontrolle

This European Standard was approved by CEN on 27 June 2003.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



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# Foreword

This document (EN 14607-1:2004) has been prepared by CMC.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2005, and conflicting national standards shall be withdrawn at the latest by February 2005.

It is based on a previous version[1)] prepared by the ECSS Engineering Standards Working Group, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board. The European Cooperation for Space Standardization (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 document 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.

The formulation of this document takes into account the existing ISO 9000 family of documents.

EN 14607 Space engineering - Mechanical is published in 8 Parts:

- Part 1: Thermal control
- Part 2: Structural
- Part 3: Mechanisms
- Part 4: ECLS
- Part 5: Propulsion
  - Part 5.1: Liquid and electric propulsion for spacecraft
  - Part 5.2: Solid propulsion for spacecraft, solid and liquid propulsion for launchers
- Part 6: Pyrotechnics
- Part 7: Mechanical parts
- Part 8: Materials



According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1) ECSS-E-30 Part 1A.

# 1 Scope

EN 14607 Part 1 of Space engineering - Mechanical specifies requirements for the discipline of thermal engineering.

This document specifies the requirements for the definition, analysis, design, manufacture, verification and in-service operation of thermal control subsystems of spacecraft and other space products.

This document applies to the thermal engineering activities of all spacecraft and space related products for all thermal aspects and temperature levels for space products.

For this document, the complete temperature scale is divided into three ranges defined as follows:

- Cryogenic temperature range, below 120 K;
- Conventional temperature range, between 120 K and 420 K;
- High temperature range, above 420 K.

The core part of this document concerns the conventional temperature range; complementary information, requirements and definitions for the cryogenic and high temperature range respectively are provided in annexes B and C.

When viewed from the perspective of a specific project context, the requirements defined in this document should be tailored to match the genuine requirements of a particular profile and circumstances of a project.



NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific project by selection, and in some exceptional cases, modification of existing or addition of new requirements.



This document is applicable to:

- thermal engineering activities of all space and space related products, covering all thermal engineering aspects involved in the achievement of the required thermal performance, particularly: design, verification, manufacturing and in service operations;
- thermal control subsystem and to relevant parts of all space products.

# 2 Normative references

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

EN 13291-2:2003, *Space product assurance - General requirements - Part 2: Quality assurance*

EN 13291-3:2003, *Space product assurance - General requirements - Part 3: Materials, mechanical parts and processes.*

EN 13290-5:2001, *Space project management — General requirements — Part 5: Configuration management*

EN 13701:2001, *Space systems - Glossary of terms.*

EN 14725:2003, *Space engineering — Verification*

EN ISO 14620-1:2002, *Space systems — Safety requirements — Part 1: System safety (ISO 14620-1:2002)*

ISO 128, *Technical drawings — General principles of presentation*

ECSS-E-10, *Space engineering — System engineering*

# 3 Terms, definitions and abbreviated terms

## 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13701:2001 and the following apply.

**3.1.1**
**acceptance margin**
contingency agreed between system authority and TCS to account for unpredictable TCS-related events (see Figure 1)

NOTE The acceptance margin is the difference between the upper or lower acceptance temperature and the upper or lower design temperature (for both operating and non-operating mode).

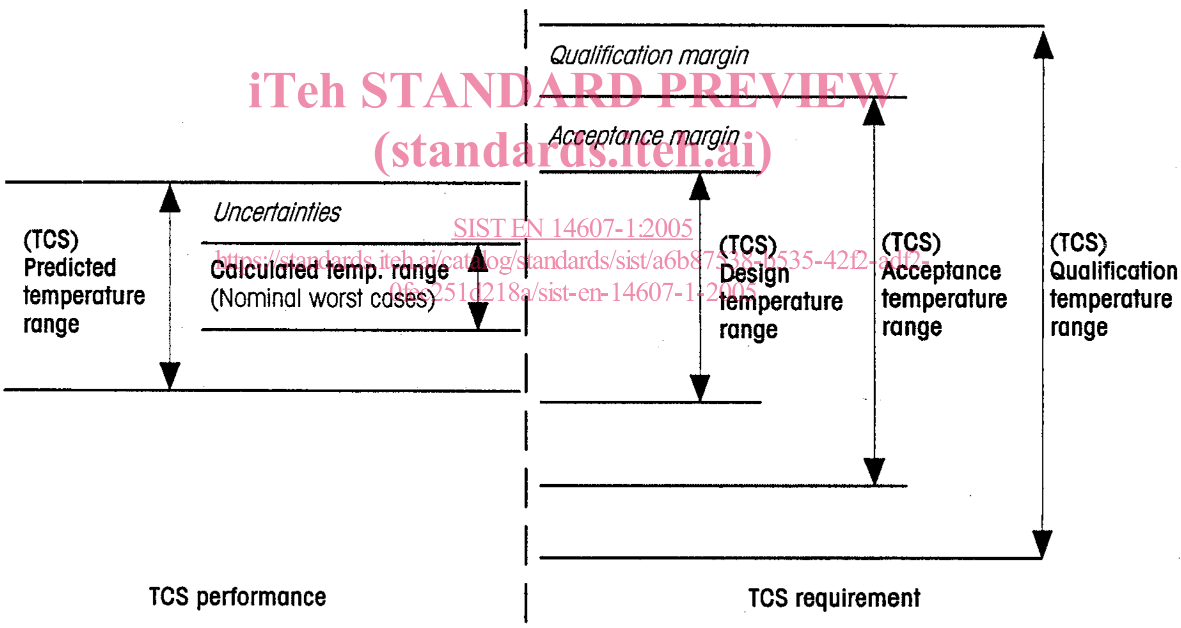




**Figure 1 — Temperature definitions for thermal control system (TCS)**

**3.1.2**
**acceptance temperature range**
temperature range (see Figure 1) obtained from the relevant qualification temperature range after subtraction of suitable qualification margins specified for the operating and non-operating mode and the switch-on condition of a unit

NOTE The acceptance temperature range is the extreme temperature range that a unit can reach, but never exceed, during all envisaged mission phases (based on worst case assumptions).

**3.1.3**
**acceptance test (system level)**
verification process that demonstrates that an item is acceptable for flight

NOTE During the acceptance test, the unit TRPs are exposed to temperatures within and not exceeding their acceptance temperature range.

**3.1.4**
**assembly (thermal)**
combination of parts, components and units which forms a functional entity

**3.1.5**
**calculated temperature range**
temperature range (see Figure 1) obtained by analysis or other means for the operating and non-operating mode and the minimum switch-on condition of a unit, based on worst case considerations (i.e. an appropriate combination of external fluxes, materials properties and unit dissipation profiles to describe hot and cold conditions) excluding failure cases

NOTE The calculated temperature range plus any uncertainties is limited to the specified design temperature range. During the course of a project these uncertainties change from initial estimates into a value determined by analysis.

**3.1.6**
**climatic test**
test conducted to demonstrate the capability of an item to operate satisfactorily or to survive without degradation under specific environmental conditions (e.g. pressure, humidity and composition of atmosphere) at predefined hot and cold temperatures



**3.1.7**
**component (thermal)**
piece of thermal hardware which by further subdivision loses its functionality, but is not necessarily destroyed



**3.1.8**
**conductive interface temperature**
temperature used to define the conductive heat exchange between an item and the supporting structure

NOTE 1 Depending on the degree of interaction between the item (via for example, its temperature, contact area, contact conductance) and the supporting structure, the conductive interface temperature, is reassessed in an iterative way during the course of a project.

NOTE 2 In case the expected conditions cannot be correctly simulated, the qualification process can include a flight demonstration (e.g. launchers and re-entry vehicles).

**3.1.9**
**correlation**
correspondence between analytical predictions and test results

**3.1.10**
**design temperature range**
temperature range (see Figure 1) specified for the operating and non-operating mode and the switch-on condition of a unit, obtained by subtracting suitable acceptance margins from the relevant acceptance temperature range

NOTE 1 This temperature range represents the requirements for the TCS design activities.

NOTE 2 The use of the term "operating temperature range" or "operational temperature range" to denominate the design temperature range, shall not be used.

**3.1.11**
**geometrical mathematical model (GMM)**
mathematical model in which an item and its surroundings are represented by radiation exchanging surfaces characterised by their thermo-optical properties

NOTE The GMM generates the absorbed environmental heat fluxes and the radiative couplings between the surfaces.

**3.1.12**
**heat dissipation or heat flow rate**
thermal energy (heat) divided by time, expressed in joules per second, or watts

**3.1.13**
**heat flux or heat flow rate density**
thermal energy (heat) divided by time and unit area perpendicular to the flow path, expressed in $W/m^2$

**3.1.14**
**heat lift**
transfer of a specified heat flow rate from a specified lower to a higher temperature (e.g. heat pumps)

**3.1.15**
**heat storage**
capability to store a specified amount of heat at a specified temperature, or over a specified temperature range

**3.1.16**
**item (thermal)**
term used in this document to designate, replace any or all of the following terms: part, component, unit, assembly, complete spacecraft

**3.1.17**
**infrared test**
thermal test method in which the solar and planetary radiation are simulated by locally heating the spacecraft surface to the predicted input level using infrared techniques (e.g. infrared lamps and heater mats)



**3.1.18**
**minimum switch-on temperature**
minimum temperature at which a unit can be switched from the non-operating mode to the operating mode and functions nominally when the unit temperature is brought back to the relevant operating mode temperatures



**3.1.19**
**natural environment**
set of environmental conditions defined by the external physical surrounding for a certain mission (e.g. the heat fluxes by the sun, the planets and satellites, the air pressure and density)

**3.1.20**
**part (thermal)**
smallest piece used in thermal hardware which, when subdivided any further, is destroyed (e.g. foils, thermal washers, bolt and pipe)

**3.1.21**
**predicted temperature range**
temperature range (see Figure 1) obtained from the calculated temperature range increased by the uncertainties

**3.1.22**
**qualification margin**
contingency defined by the system authority to account for any unexpected events (see Figure 1)

NOTE For temperatures, the qualification margin is the difference between the upper or lower qualification temperature and the upper or lower acceptance temperature (for operating and non-operating mode).

**3.1.23**
**qualification temperature range**
temperature range (see Figure 1) specified for the operating and non-operating mode and the switch-on condition of a unit, for which this unit is guaranteed to function nominally fulfilling all required performances with the required reliability

**3.1.24**
**qualification tests (system level)**
verification process that demonstrates that hardware functions within performance specification under simulated conditions more severe than those expected during the mission

NOTE During the qualification tests, unit temperature reference points (TRPs) are exposed to temperatures within but not exceeding the qualification temperature range.

**3.1.25**
**radiative sink temperature**
virtual black body radiation temperature used to define the equivalent radiative thermal load on an item

NOTE 1 The radiative sink temperature includes both the natural environment load (solar, planetary albedo and infrared fluxes) and the radiative exchanges with other items.

NOTE 2 The radiative sink temperature is typically used to provide a simplified interface for an item, to provide a means for parameter studies thus avoiding extensive calculations or to define adequate radiative boundary conditions for thermal tests.

NOTE 3 The sink temperature $T_{Sink}$ of an item $i$ with a temperature $T_i$ in radiative exchange with $n$ items $j$ and submitted to external radiative environmental fluxes is calculated according to the formula:

$$T_{Sink,\,rad}(i) = \sqrt[4]{T_i^4 + \frac{\sum_{j=1}^{n} R_{ij}(T_j^4 - T_i^4)}{\epsilon A_i} + \frac{P_s}{\sigma\varepsilon A_i} + \frac{P_A}{\sigma\varepsilon A_i} + \frac{P_{IR}}{\sigma\varepsilon A_i}}$$



where

$\epsilon$ emissivity of item $i$;



$P_s$ absorbed solar flux on item $i$ ;

$P_A$ absorbed (planetary) albedo flux on item $i$ ;

$P_{IR}$ absorbed infrared (planetary) flux on item $i$ ;

$R_{ij}$ radiative coupling between item $i$ and item $j$;

$T_j$ temperature of item $j$;

$\sigma$ Stefan-Boltzmann constant;

$A_i$ radiative exchange area of item $i$.

NOTE 4 The radiative sink temperature formula is applicable to steady-state conditions only. Depending on the degree of interaction between the item $i$ (via its temperature, surface properties, dimensions, heat dissipation) and the radiative sink, the simplified approach using the radiative sink temperature is performed in an iterative way during the course of a project.

**3.1.26**
**reference case**
set of parameters (i.e. environmental, material properties, dissipation profiles) used for comparable analysis

NOTE A reference case can be a design case.

**3.1.27**
**solar simulation test**
test method in which the intensity, spectral distribution, uniformity and collimation angle of the solar radiation are reproduced within acceptable limits

**3.1.28**
**success criteria**
predefined value or set of values, for one or several parameters (e.g. temperature, temperature gradient) which shall be achieved

NOTE Success criteria can be defined for analytical activities (i.e. correlation) or for testing activities.

**3.1.29**
**system interface temperature point**
physical point appropriately located on the structure of the system which can be used to evaluate the thermal conductive interaction between a unit and the spacecraft system

**3.1.30**
**temperature**
potential which governs the flow of energy, measured by the scale of absolute temperature, the kelvin scale (K)

NOTE Temperatures may also be expressed in degree celsius (°C).

**3.1.31**
**temperature cycle**
transition from some initial temperature condition to a predefined temperature (with stabilisation, if required) at one extreme and then to a predefined temperature (with stabilisation, if required) at the opposite extreme and returning to the initial temperature condition

**3.1.32**
**temperature difference**
difference in temperature of two points at a given time, expressed in K or °C



**3.1.33**
**temperature gradient**
vector whose direction at a given time and a given point is perpendicular to an isothermal surface at that point, and whose magnitude equals the rate of change of temperature in this direction, expressed in K/m



**3.1.34**
**temperature reference point (TRP)**
physical point located on a unit and unequivocally defined in the unit's ICD

NOTE 1 The TRP provides a simplified representation of the unit thermal status.

NOTE 2 Depending on the unit dimensions, more than one temperature reference point may be defined.

**3.1.35**
**temperature stability**
condition when the temperature variation is less than a defined (small) value for a given point

**3.1.36**
**temperature uniformity**
condition when the temperature difference or the temperature gradient at a given time is less than a defined (small) value for a given surface or a given body

**3.1.37**
**temperature variation**
change of temperature with respect to time for a given point, expressed in K/s

**3.1.38**
**thermal balance test**
test conducted to verify the adequacy of the thermal model and the adequacy of the thermal design

**3.1.39**
**thermal design case**
set of parameters (e.g. environmental, material properties and dissipation profiles) used for the detailed definition and sizing of the thermal control subsystem

**3.1.40**
**thermal mathematical model (TMM)**
lumped parameters model in which an item and its surroundings are represented by concentrated thermal capacitance nodes, each with one representative temperature, coupled by a network made of thermal conductors (radiative, conductive and convective)

NOTE 1 For thermo-hydraulic modelling enthalpy and fluidic conductors are specified.

NOTE 2 A TMM generates for all nodes a temperature history, an energy balance; in addition pressure drops and mass flow rates.

**3.1.41**
**thermal node**
representation of a specific volume of an item with a representative temperature, representative material properties and representative pressure (diffusion node) used in a mathematical lumped parameter approach

NOTE Other nodes also used in a TMM include arithmetic or boundary nodes.

**3.1.42**
**thermal vacuum test**
test conducted to demonstrate the capability of the test item to operate satisfactorily or to survive without degradation in vacuum at predefined hot and cold temperatures



**3.1.43**
**uncertainty**
lack of certitude resulting from inaccuracies of input parameters, analysis process, or both (see Figure 1)



NOTE Temperature uncertainties are typically caused by inaccuracies in, for example, material properties, environmental data or modelling assumptions.

**3.1.44**
**unit**
finished product with a given internal design

NOTE 1 The only interaction between a unit and TCS is via the control of external means (e.g. surface coatings, mounting method) and temperature information is derived from the temperature at the unit temperature reference point(s).

NOTE 2 All data relevant for TCS are included in an Interface Control Document (ICD)

## 3.2 Definitions for unit internal thermal design

In addition to above thermal definitions, the following specific definitions are applicable to the internal thermal design of units and are illustrated in Figure 2.

**3.2.1**
**unit acceptance test temperature range**
extreme range which is used for unit acceptance at unit level (see Figure 2)

NOTE The unit acceptance temperature range is obtained from the (TCS) acceptance temperature range as defined in Figure 1 after the addition of a suitable value to account for test inaccuracies.

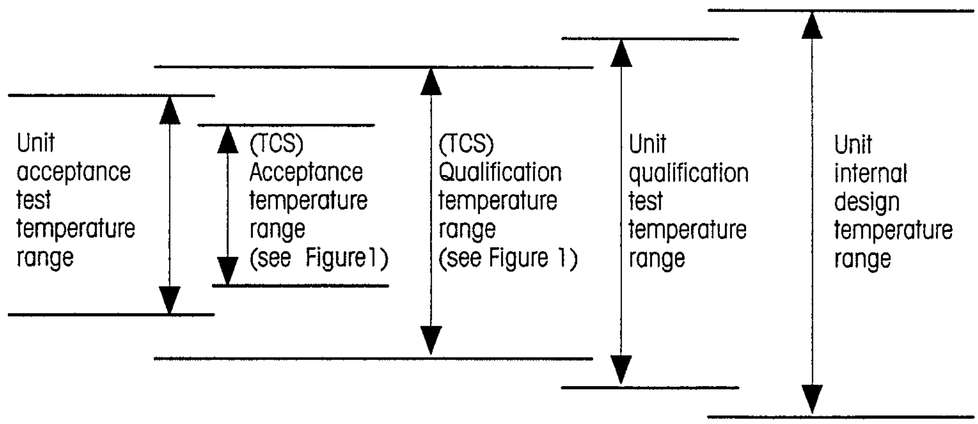


**Figure 2 —Temperature definitions for unit thermal design**

**3.2.2**
**unit internal design temperature range**
extreme range for which components or parts are selected (see Figure 2)

NOTE These unit internal design temperatures are derived from unit thermal calculations including uncertainties and unit margins.



**3.2.3**
**unit qualification test temperature range**
extreme range used for unit qualification at unit level (see Figure 2)



NOTE The unit qualification temperature range is obtained from the qualification temperature range as defined in Figure 1 after addition of a suitable value to account for test inaccuracies.

## 3.3 Abbreviated terms

The following abbreviated terms are defined and used within this document.

| Abbreviation | Meaning |
|---|---|
| **ABM** | apogee boost motor |
| **AOCS** | attitude and orbit control system |
| **CCS** | cryogenic cooling system |
| **DRD** | document requirements definition |
| **DRL** | document requirements list |
| **EEE** | electronic, electrical, electromechanical |
| **EM** | engineering model |
| **EMC** | electromagnetic compatibility |
| **ESD** | electrostatic discharge |
| **FEM** | finite element methods |
| **FM** | flight model |