SLOVENSKI STANDARD
kSIST-TP FprCEN/CLC/TR 17603-31-09:2021

01-maj-2021

Vesoljska tehnika - Priročnik za toplotno zasnovo - 9. del: Radiatorji

Space Engineering - Thermal design handbook - Part 9: Radiators

Raumfahrttechnik - Handbuch für thermisches Design - Teil 9: Radiatoren

Ingénierie spatiale - Manuel de conception thermique - Partie 9: Radiateurs

Ta slovenski standard je istoveten z: **FprCEN/CLC/TR 17603-31-09**

ICS:

49.140	Vesoljski sistemi in operacije	Space systems and operations

kSIST-TP FprCEN/CLC/TR 17603-31-09:2021 **en,fr,de**

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

FINAL DRAFT
FprCEN/CLC/TR 17603-31-09

February 2021

ICS 49.140

English version

Space Engineering - Thermal design handbook - Part 9: Radiators

Ingénierie spatiale - Manuel de conception thermique - Partie 9: Radiateurs

Raumfahrttechnik - Handbuch für thermisches Design - Teil 9: Radiatoren

This draft Technical Report is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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Ref. No. FprCEN/CLC/TR 17603-31-09:2021 E

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European Foreword

This document (FprCEN/CLC/TR 17603-31-09:2021) has been prepared by Technical Committee CEN/CLC/JTC 5 "Space", the secretariat of which is held by DIN.

This document is currently submitted to the Vote on TR.

It is highlighted that this technical report does not contain any requirement but only collection of data or descriptions and guidelines about how to organize and perform the work in support of EN 16603-31.

This Technical report (FprCEN/CLC/TR 17603-31-09:2021) originates from ECSS-E-HB-31-01 Part 1A .

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This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any TR covering the same scope but with a wider domain of applicability (e.g.: aerospace).

This document is currently submitted to the CEN CONSULTATION.

1 Scope

In this Part 9 of the spacecraft thermal control and design data handbooks, view factors of diffuse and specular thermal surfaces are discussed.

For diffuse surfaces, calculations are given for radiation emission and absorption between different configurations of planar, cylindrical, conical, spherical and ellipsoidal surfaces for finite and infinite surfaces.

For specular surfaces the affect of reflectance on calculations for view factors is included in the calculations. View factors for specular and diffuse surfaces are also included.

The Thermal design handbook is published in 16 Parts

TR 17603-31-01	Thermal design handbook – Part 1: View factors
TR 17603-31-02	Thermal design handbook – Part 2: Holes, Grooves and Cavities
TR 17603-31-03	Thermal design handbook – Part 3: Spacecraft Surface Temperature
TR 17603-31-04	Thermal design handbook – Part 4: Conductive Heat Transfer
TR 17603-31-05	Thermal design handbook – Part 5: Structural Materials: Metallic and Composite
TR 17603-31-06	Thermal design handbook – Part 6: Thermal Control Surfaces
TR 17603-31-07	Thermal design handbook – Part 7: Insulations
TR 17603-31-08	Thermal design handbook – Part 8: Heat Pipes
TR 17603-31-09	Thermal design handbook – Part 9: Radiators
TR 17603-31-10	Thermal design handbook – Part 10: Phase – Change Capacitors
TR 17603-31-11	Thermal design handbook – Part 11: Electrical Heating
TR 17603-31-12	Thermal design handbook – Part 12: Louvers
TR 17603-31-13	Thermal design handbook – Part 13: Fluid Loops
TR 17603-31-14	Thermal design handbook – Part 14: Cryogenic Cooling
TR 17603-31-15	Thermal design handbook – Part 15: Existing Satellites
TR 17603-31-16	Thermal design handbook – Part 16: Thermal Protection System

2 References

EN Reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS System - Glossary of terms
TR 17603-31-03	ECSS-E-HB-31-01 Part 3	Thermal design handbook – Part 3: Spacecraft Surface Temperature

All other references made to publications in this Part are listed, alphabetically, in the **Bibliography**.

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.2 Symbols

A_i	surface area of the i-th surface, [m^2]
B_i	energy flux leaving surface, *i*. often called radiosity, [W.m^{-2}]
F_{ij}	view factor from diffuse surface, A_i to diffuse surface, A_j
$F_{(i1,i2,...in)(j1,j2,...jn)}$	view factor from the ensemble of diffuse surfaces, A_{i1}, A_{i2},...A_{in} to the ensemble of diffuse surfaces, A_{j1}, A_{j2},...A_{jn}
F_{ij}^s	view factor from specular surface A_i to specular surface A_j
H_i	energy flux incident on surface *i*, [W.m^{-2}]
K_{i2}	term which appears in the expression for the view factor between elements of parallel plates, $K_{i2} = A_iF_{ii'}$
$K_{mn}(i,j,k,p,q,...)$	fraction of the radiative energy leaving A_m which reaches A_n after *i* perfectly specular reflections from surface A_i, *j* from surface A_j, *k* from surface A_k,...
S	distance between two differential elements, [m]
T	temperature, [K]
β_i	angle from normal to surface *i*, [angular degrees]
ε	hemispherical emittance of a (diffuse-gray) surface
ρ^d	hemispherical diffuse reflectance of a (diffuse-gray) surface

ρ^s	specular reflectance of a (gray) surface, it is assumed to be independent of incident angle
σ	Stefan-Boltzmann constant, S = 5,6697x10^{-8} W.m^{-2}.K^{-4}

Other symbols, mainly used to define the geometry of the configurations, are introduced when required.

4 Diffuse surfaces

4.1 General

The view factor, F_{12}, between the diffuse surface A_1 and A_2, is the fraction of the energy leaving the isothermal surface A_1 that arrives at A_2.

If the receiver surface is infinitesimal, the view factor is infinitesimal for both infinitesimal and finite emitting surfaces, and is given by the expression

$$dF_{12} = \frac{\cos\beta_1 \cos\beta_2}{\pi S^2} dA_2 \qquad [4\text{-}1]$$

when both surfaces are infinitesimal, and by

$$dF_{12} = \frac{dA_2}{A_1} \int_{A_1} \frac{\cos\beta_1 \cos\beta_2}{\pi S^2} dA_1 \qquad [4\text{-}2]$$

when A_1 is finite.

If the receiver surface is finite, the view factor is finite for both infinitesimal and finite emitting surfaces, and is given by the expression

$$F_{12} = \int_{A_2} \frac{\cos\beta_1 \cos\beta_2}{\pi S^2} dA_2 \qquad [4\text{-}3]$$

when A_1 is infinitesimal, and by

$$F_{12} = \frac{1}{A_1} \int_{A_1} \int_{A_2} \frac{\cos\beta_1 \cos\beta_2}{\pi S^2} dA_2 \, dA_1 \qquad [4\text{-}4]$$

when A_1 is finite.

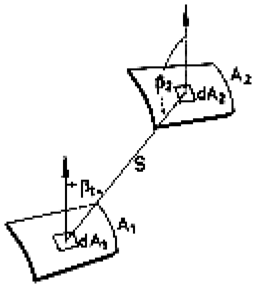

Figure 4-1: Geometric notation for view factors between diffuse surface.

Regardless of which surfaces are considered, their view factors satisfy the following reciprocity relation:

$A_1F_{12} = A_2F_{21}$

If we consider the diffuse surfaces A_1, A_2 and A_3, the view factor between the surfaces A_1 and $A_2 + A_3$ is

$F_{1(2,3)} = F_{12} + F_{13}$,

when the receiver surface is formed by two surfaces, and

$$F_{(2,3)1} = \frac{A_2F_{21} + A_3F_{31}}{A_2 + A_3} \qquad [4\text{-}5]$$

when the emitting surface is formed by two surfaces. notice that the notation $F_{1(2,3)}$ and $F_{(2,3)1}$ will be used in the following data sheets.

When an enclosure of N surfaces $A_1,A_2,....,A_n$ is considered, their view factors satisfy the relation

$$\sum_{j=1}^{N} F_{ij} = 1 \qquad [4\text{-}6]$$

for any surface A_i. This relationship results from the fact that the overall heat transfer in the enclosure should be zero.

4.2 Infinitesimal to finite surfaces

4.2.1 Planar to planar

4.2.1.1 Two-dimensional configurations

A plane point source dA_1 and any surface A_2 generated by an infinitely long line moving parallel to itself and to the plane dA_1.