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Vesoljska tehnika - Oprema za dvofazni toplotni transport

Space engineering - Two-phase heat transport equipment

Raumfahrttechnik - Ausrüstung für Zwei-Phasen-Wärmetransport

Ingénierie spatiale - Equipements de transfert de chaleur à deux phases

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English version

Space engineering - Two-phase heat transport equipment

Ingénierie spatiale - Equipements de transfert de chaleur à deux phases

Raumfahrttechnik - Ausrüstung für Zwei-Phasen-Wärmetransport

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European foreword

This document (EN 16603-31-02:2015) has been prepared by Technical Committee CEN/CLC/TC 5 "Space", the secretariat of which is held by DIN.

This standard (EN 16603-31-02:2015) originates from ECSS-E-ST-31-02C.

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of an identical text or by endorsement, at the latest by March 2016, and conflicting national standards shall be withdrawn at the latest by March 2016.

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Introduction

This Standard is based on ESA PSS-49, Issue 2 "Heat pipe qualification requirements", written 1983, when the need for heat pipes in several ESA projects had been identified. At that time a number of European development activities were initiated to provide qualified heat pipes for these programmes, which culminated in a first heat pipe application on a European spacecraft in 1981 (MARECS, BR-200, ESA Achievements - More Than Thirty Years of Pioneering Space Activity, ESA November 30, 2001), followed by a first major application on a European communication satellite in 1987 (TV-SAT 1, German Communication Satellites).

ESA PSS-49 was published at a time, when knowledge of heat pipe technology started to evolve from work of a few laboratories in Europe (IKE, University Stuttgart, EURATOM Research Centre, Ispra). Several wick designs, material combinations and heat carrier fluids were investigated and many process related issues remained to be solved. From today's view point the qualification requirements of ESA PSS-49 appear therefore very detailed, exhaustive and in some cases disproportionate in an effort to cover any not yet fully understood phenomena. As examples the specified number of qualification units (14), the number of required thermal cycles (800) and the extensive mechanical testing (50 g constant acceleration, high level sine and random vibration) can be cited.

The present Standard takes advantage of valid requirements of ESA PSS-49, but reflects at the same time today's advanced knowledge of two-phase cooling technology, which can be found with European manufacturers. This includes experience to select proven material combinations, reliable wick and container designs, to apply well-established manufacturing and testing processes, and develop reliable analysis tools to predict in-orbit performance of flight hardware. The experience is also based on numerous successful two-phase cooling system application in European spacecraft over the last 20 years.

Besides stream-lining the ESA PSS-49, to arrive at today's accepted set of heat pipe qualification requirements, the following features have also been taken into account:

- Inclusion of qualification requirements for two-phase loops (CPL, LHP),
- Reference to applicable requirements in other ECSS documents,
- Formatting to recent ECSS template in order to produce a document, which can be used in business agreements between customer and supplier.

1 Scope

This standard defines requirements for two-phase heat transportation equipment (TPHTE), for use in spacecraft thermal control.

This standard is applicable to new hardware qualification activities.

Requirements for mechanical pump driven loops (MPDL) are not included in the present version of this Standard.

This standard includes definitions, requirements and DRDs from ECSS-E-ST-10-02, ECSS-E-ST-10-03, and ECSS-E-ST-10-06 applicable to TPHTE qualification. Therefore, these three standards are not applicable to the qualification of TPHTE.

This standard also includes definitions and part of the requirements of ECSS-E-ST-32-02 applicable to TPHTE qualification. ECSS-E-ST-32-02 is therefore applicable to the qualification of TPHTE.

This standard does not include requirements for acceptance of TPHTE.

This standard may be tailored for the specific characteristic and constrains 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 revision 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 more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system - Glossary of terms
EN 16603-31	ECSS-E-ST-31	Space engineering - Thermal control general requirements
EN 16603-32	ECSS-E-ST-32	Space engineering - Structural general requirements
EN 16603-32-01	ECSS-E-ST-32-01	Space engineering - Fracture control
EN 16603-32-02	ECSS-E-ST-32-02	Space engineering - Structural design and verification of pressurized hardware
EN 16602-70	ECSS-Q-ST-70	Space product assurance - Materials, mechanical parts and processes
	EN 9100:2009	Aerospace series - Quality management systems - Requirements for Aviation, Space and Defense Organizations

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-E-ST-00-01 apply.

For the purpose of this standard, the following terms and definitions from ECSS-E-ST-10-02 apply:

analysis

qualification stage

review-of-design (ROD)

For the purpose of this standard, the following terms and definitions from ECSS-E-ST-32-02 apply:

burst pressure

differential pressure

external pressure

internal pressure

leak-before-burst (LBB)

pressure vessel (PV)

pressurized hardware (PH)

proof test

3.2 Terms specific to the present standard

3.2.1 capillary driven loop (CDL)

TPL, in which fluid circulation is accomplished by capillary action (capillary pump)

NOTE See TPL definition in 3.2.21.

3.2.2 capillary pumped loop (CPL)

CDL with the fluid reservoir separated from the evaporator and without a capillary link to the evaporator

NOTE See CDL definition in 3.2.1.

3.2.3 constant conductance heat pipe (CCHP)

heat pipe with a fixed thermal conductance between evaporator and condenser at a given saturation temperature

NOTE See heat pipe definition in 3.2.7.

3.2.4 dry-out

depletion of liquid in the evaporator section at high heat input when the capillary pressure gain becomes lower than the pressure drop in the circulating fluid

3.2.5 effective length

heat pipe length between middle of evaporator and middle of condenser for configurations with one evaporator and one condenser only

NOTE Used to determine the heat pipe transport capability (see 3.2.10).

3.2.6 exposure temperature range

maximum temperature range to which a TPHTE is exposed during its product life cycle and which is relevant for thermo-mechanical qualification

NOTE 1 The internal pressure at the maximum temperature of this range defines the MDP for the pressure vessel qualification of a TPHTE.

NOTE 2 The extreme temperatures of this range can be below freezing and / or above critical temperatures of the working fluid.

NOTE 3 In other technical domains, this temperature range is typically called non-operating temperature range (see clause 4 for additional explanation).

3.2.7 heat pipe (HP)

TPHTE consisting of a single container with liquid and vapour passages arranged in such a way that the two fluid phases move in counter flow

NOTE 1 See TPHTE definition in 3.2.20.

NOTE 2 The capillary structure in a heat pipe extends over the entire container length.

3.2.8 heat pipe diode (HPD)

heat pipe, which transports heat based on evaporation and condensation only in one direction

NOTE See heat pipe definition in 3.2.7.

3.2.9 loop heat pipe (LHP)

CDL with the fluid reservoir as integral part of the evaporator

NOTE 1 See CDL definition in 3.2.1.

NOTE 2 The reservoir can be separated, but has a capillary link to the evaporator.

3.2.10 heat transport capability

maximum amount of heat, which can be transported in a TPHTE from the evaporator to the condenser

NOTE For heat pipes it is the maximum heat load expressed in [Wm] (transported heat x effective length).

3.2.11 maximum design pressure (MDP)

maximum allowed pressure inside a TPHTE during product life cycle

NOTE The product life cycle starts after acceptance of the product for flight.

3.2.12 mechanical pump driven loop (MPDL)

TPL, in which fluid circulation is accomplished by a mechanical pump

NOTE See TPL definitions in 3.2.21.

3.2.13 product life cycle

product life starting from the delivery of the TPHTE hardware until end of service live

3.2.14 reflux mode

operational mode, where the liquid is returned from the condenser to the evaporator by gravitational forces and not by capillary forces

3.2.15 start-up

operational phase starting with initial supply of heat to the evaporator until nominal operational conditions of the device are established

3.2.16 sub-cooling

temperature difference between average CDL reservoir temperature and the temperature of the liquid line at the inlet to the reservoir

NOTE The average CDL reservoir temperature represents the saturation temperature inside the reservoir.

3.2.17 thermal performance temperature range

temperature range for which a TPHTE is thermally qualified

NOTE In the thermal performance temperature range a thermal performance map exists.

3.2.18 tilt for HP

height of the evaporator (highest point) above the condenser (lowest point) during ground testing

NOTE This definition is valid for a configuration with one evaporator and one condenser (see Figure 3-1).

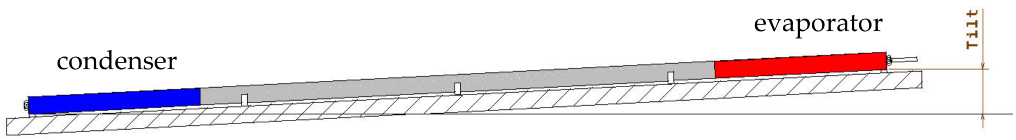

Figure 3-1: Tilt definition for HP

3.2.19 tilt for LHP

height of the evaporator (highest point) above the reservoir (lowest point) during ground testing

NOTE See Figure 3-2.

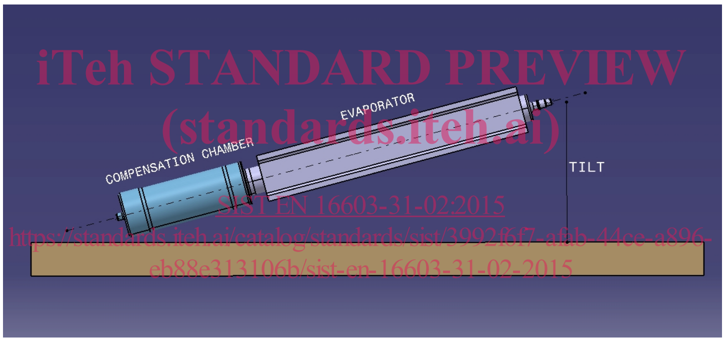

Figure 3-2: Tilt definition for LHP

3.2.20 two-phase heat transport equipment (TPHTE)

hermetically closed system filled with a working fluid and transporting thermal energy by a continuous evaporation/condensation process using the latent heat of the fluid

NOTE 1 A fluid evaporates in the heat input zone (evaporator) and condenses in the heat output zone (condenser).

NOTE 2 This is in contrast to a single-phase loop where the sensible heat of a liquid is transported (a liquid heats up in the heat input zone and cools down in the heat output zone).

3.2.21 two-phase loop (TPL)

TPHTE with physically separated vapour and liquid transport lines forming a closed loop

NOTE See TPHTE definition in 3.2.20.

3.2.22 variable conductance heat pipe (VCHP)

heat pipe with an additional non-condensable gas reservoir allowing a variable thermal conductance between evaporator and condenser

NOTE 1 See heat pipe definition in 3.2.7.

NOTE 2 The variation in thermal conductance is generally accomplished by regulating the volume of a non-condensable gas plug reaching into the condenser zone, which in turn varies the effective condenser length.

NOTE 3 The variation of the gas volume can be performed by active or passive means.

3.3 Abbreviated terms

The following abbreviations are defined and used within this standard:

Abbreviation	Meaning
CCHP	constant conductance heat pipe
CDL	capillary driven loop
CPL	capillary pumped loop
CTE	coefficient of thermal expansion
DRD	document requirements definition
HP	heat pipe
HPD	heat pipe diode
LBB	leak before burst
LHP	loop heat pipe
MDP	maximum design pressure
MPDL	mechanical pump driven loop
MSPE	metallic special pressurized equipment
NDI	non-destructive inspection
PH	pressurized hardware
ROD	review-of-design
SPE	special pressurized equipment
TCS	thermal control (sub)system
TPHTE	two-phase heat transport equipment
TPL	two-phase loop
TS	technical requirement specification
VCHP	variable conductance heat pipe
VP	verification plan