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Flüssige und elektrische Antriebe von Raumfahrzeugen;
Englische Fassung EN 16603-35-01:2014**

Space engineering –
Liquid and electric propulsion for spacecraft;
English version EN 16603-35-01:2014

Ingénierie spatiale –
Propulsion liquide et électrique pour satellites;
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Nationales Vorwort

Dieses Dokument (EN 16603-35-01:2014) wurde vom Technischen Komitee CEN/CLC/TC 5 „Raumfahrt“ erarbeitet, dessen Sekretariat vom DIN (Deutschland) gehalten wird.

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Dieses Dokument (EN 16603-35-01:2014) basiert auf ECSS-E-ST-35-01C.

Dieses Dokument ersetzt DIN EN 14607-5-1:2006-12.

Dieses Dokument enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung von EN 16603-35-01:2014.

Dieses Dokument wurde speziell zur Behandlung von Raumfahrtssystemen erarbeitet und hat daher Vorrang vor jeglicher Europäischer Norm, da es denselben Anwendungsbereich hat, jedoch über einen größeren Geltungsbereich (z. B. Luft- und Raumfahrt) verfügt.

Änderungen

Gegenüber DIN EN 14607-5-1:2006-12 wurden folgende Änderungen vorgenommen:

- a) Norm-Nummer geändert;
- b) keinerlei Änderungen des Textes.

Frühere Ausgaben

DIN EN 14607-5-1: 2006-12

Nationaler Anhang NA (informativ)

Begriffe

3 Begriffe und Abkürzungen

3.1 Begriffe aus anderen Normen

Für die Anwendung dieses Dokuments gelten die Begriffe nach ECSS-S-ST-00-01 und nach ECSS-E-ST-35.

3.2 Abkürzungen

Für die Anwendung dieses Dokuments gelten die Abkürzungen nach ECSS-S-ST-00-01.

English version

Space engineering - Liquid and electric propulsion for spacecraft

Ingénierie spatiale - Propulsion liquide et électrique pour satellites

Raumfahrttechnik - Flüssige und elektrische Antriebe von Raumfahrzeugen

This European Standard was approved by CEN on 23 February 2014.

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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 and CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Foreword

This document (EN 16603-35-01:2014) has been prepared by Technical Committee CEN/CLC/TC 5 "Space", the secretariat of which is held by DIN.

This standard (EN 16603-35-01:2014) originates from ECSS-E-ST-35-01C.

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 2015, and conflicting national standards shall be withdrawn at the latest by March 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 14607-5-1:2004.

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

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

Introduction

The ECSS Propulsion standards structure is as follows.

ECSS-E-ST-35 Propulsion general requirements

- Standards, covering particular type of propulsion
 - ECSS-E-ST-35-01 Liquid and electric propulsion for spacecrafts
 - ECSS-E-ST-35-02 Solid propulsion for spacecrafts and launchers
 - ECSS-E-ST-35-03 Liquid propulsion for launchers
- Standard covering particular propulsion aspects
 - ECSS-E-ST-35-06 Cleanliness requirements for spacecraft propulsion hardware
 - ECSS-E-ST-35-10 Compatibility testing for liquid propulsion systems

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Scope

This Standard defines the regulatory aspects applicable to elements and processes for liquid, including cold gas, and electrical propulsion for spacecraft. It specifies the activities to be performed in the engineering of such propulsion systems, their applicability, and defines the requirements for the engineering aspects: functional, interfaces, environmental, design, quality factors, operational and verification.

General requirements applying to all type of Propulsion Systems Engineering are defined in ECSS-E-ST-35.

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

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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 16601-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
EN 16603-10	ECSS-E-ST-10	Space engineering – System engineering general requirements
EN 16603-20	ECSS-E-ST-20	Space engineering – Electrical and electronic
EN 16603-20-06	ECSS-E-ST-20-06	Space engineering – Spacecraft changing
EN 16603-20-07	ECSS-E-ST-20-07	Space engineering – Electromagnetic compatibility
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 16603-35	ECSS-E-ST-35	Space engineering – Propulsion general requirements
EN 16602-30	ECSS-Q-ST-30	Space product assurance – Dependability

Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 and ECSS-E-ST-35 apply.

3.2 Abbreviated terms

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

Liquid propulsion systems for spacecraft

4.1 Overview

Liquid propulsion systems for spacecraft provide the forces and torques for orbit transfer, orbit maintenance and attitude control. For manoeuvrable spacecraft, capsules and transport vehicles, they provide in addition the forces and torques for rendez-vous and docking.

Apart from what is specific for propellant combustion, liquid propulsion criteria are also applicable to cold gas propulsion systems.

The present clause 4 covers also the design and use of propulsion ground support equipment (GSE), defined in ECSS-E-ST-70.

4.2 Functional

4.2.1 Mission

- a. The propulsion system shall conform to the spacecraft mission requirements including:

1. Ground operations

NOTE For example: functional control, testing, propellant, simulant loading and spacecraft transportation.

2. Pre-launch and launch activities

NOTE For example: integration, storage, ageing and transport.

3. In-orbit operations.

NOTE For example: orbit transfer, orbit maintenance and attitude control) and the complete in-orbit life.

4.2.2 Functions

- a. The propulsion system shall provide the total impulse, minimum impulse bit, thrust levels and torques required by the AOCS.
- b. The following aspects shall be defined:
 1. Thruster firing modes
NOTE For example: steady state, off-modulation, pulse mode.
 2. Thrust level and orientation
 3. Thrust-vector control
 4. Thrust centroid time
 5. Minimum impulse bit
 6. Impulse reproducibility
 7. Total impulse
 8. Cycle life
 9. Mission life
 10. Reliability level
 11. Thrust noise
 12. Propellant gauging.
- c. The propulsion system shall fulfil its functions while subjected to the specified external loads during its mission, including:
 1. mechanical loads;
NOTE For example: quasi-static loads, vibrations, transportation.
 2. thermal loads;
 3. electrical loads.

4.3 Constraints

4.3.1 Accelerations

- a. Limits on acceleration levels, induced or experienced by the propulsion system, shall be specified at spacecraft level.
NOTE This is in order to:
 - avoid perturbations, e.g. during possible observations or experiments;
 - protect sensitive equipments;
 - design adequate tank PMD.

4.3.2 Pressure vessels and pressurized components

- a. Support structures of pressure vessels and pressurized components shall allow deformations of the vessels due to pressure or temperature changes and cycles to occur without causing stresses that exceed acceptable limits.

4.3.3 Induced and environmental temperatures

- a. The non-operating and operating temperature limitations of the propulsion system shall be specified.

4.3.4 Thermal fluxes

- a. Thruster surroundings shall conform to the radiative and conductive heat fluxes rejected by the thrusters.

4.3.5 Thruster plume effects

- a. Elements of the spacecraft sensitive to plume effects shall be identified.
- b. The allowed plume effects on elements identified in clause 4.3.5a shall be specified at spacecraft level.
- c. The generation of perturbing torques, forces, thermal gradients, contamination and erosion of surfaces, due to plume effects, shall be defined and documented accordingly.
- d. The plume analysis specified in 4.3.5c shall be reported in conformance with the Plume analysis report DRD in ECSS-E-ST-35.

4.4 Interfaces

- a. The liquid propulsion system shall conform to its specified spacecraft interfaces, including:
 - 1. Structure
 - NOTE For example: inserts, tank support structure and vibration levels.
 - 2. Thermal
 - NOTE For example: conduction, radiation levels, tank, thruster and line thermal control.
 - 3. Power
 - NOTE For example: valve drivers, pressure transducers, thermistors, heaters and thermocouples.
 - 4. Electromagnetic compatibility
 - 5. Pyrotechnics
 - NOTE For example: pyrotechnic valves.

6. Mechanisms

NOTE For example: valves, regulators, actuators and actuation system.

7. AOCS, OBDH and TM/TC.

NOTE For example: commanding, handling of data for status and health monitoring and failure detection.

b. Interfaces shall be defined:

1. For ground tests and loading activities, with the propulsion GSE.
2. For safety and prelaunch operation with the launcher authorities.

4.5 Design

4.5.1 General

4.5.1.1 Architecture

- a. The propulsion system architecture shall apply the requirements in ECSS-Q-ST-30.
- b. The propulsion system architecture shall provide evidence that fail safe, redundancy, reliability and safety requirements are met.

4.5.1.2 Replacement of parts

- a. For replacement of parts during development, testing and mission life pre-launch activities ECSS-E-ST-35, requirements 4.5.1c, d and e. shall be applied.

4.5.1.3 Water-hammer effect

- a. A water-hammer effects analysis shall be performed to support the propulsion system design and ensure proper functioning.
- b. The analysis specified in 4.5.1.3a shall be reported in conformance with the Propulsion transient analysis report DRD in ECSS-E-ST-35.

4.5.1.4 Piping

- a. A pipework design analysis shall be performed including non-consumables, cross-coupling, leakage, pressure, eigenfrequencies, water-hammer.
- b. The consequences in terms of operational restrictions shall be identified.

4.5.1.5 Closed volumes

- a. The design of the propulsion system shall prevent hazardous pressure increase in closed volumes.
- b. The need for any pressure relief capability shall be identified and analysed.

4.5.1.6 Pressure vessels and pressurized components

- a. The design of pressure vessels and pressurized components shall:
 - 1. Apply margins and factors of safety (FOS) for proof, burst and component life cycle.

NOTE See ECSS-E-ST-32-02.
 - 2. Conform to the environmental aspects, including but not limited to:
 - (a) Temperature
 - (b) Vibration
 - (c) Humidity
 - (d) Corrosive environment
 - (e) Vacuum
 - (f) Outgassing
 - (g) Radiation.

4.5.1.7 Multi-tanks

- a. If a multi-tank layout is used, inadvertent propellant transfer between tanks shall be prevented by design.
- b. If PMD tanks are being used, the consequences of selecting parallel or series connections shall be analysed.

4.5.1.8 Cycles

- a. The system and its components shall be designed for the expected number of cycles during the whole mission life, for both on-ground and in-service operation.

4.5.2 Selection

4.5.2.1 Reporting

- a. The reporting shall be done in the DJF in conformance with ECSS-E-ST-10.

4.5.2.2 General

- a. The selection shall be based on trade-off analyses of:
 - 1. The propulsion system.

NOTE For example: monopropellant, bipropellant, or cold gas.
 - 2. The operating mode.

NOTE For example: pressure regulated and blow-down.

- b. Selected materials, propellants and test fluids shall be compatible for all components.

NOTE Compatibility includes:

- dissolution;
- chemical reaction;
- erosion;
- corrosion.

4.5.2.3 Propellant selection

4.5.2.3.1 General

- a. The criteria to be used for propellant selection shall include:

1. Mission requirements
2. Resulting layout of the propulsion system
3. Availability of off-the-shelf components
4. Experience
5. Compatibility and contamination
6. Performance.

- b. The propellant shall be defined and specified including:

1. Chemical composition
2. Purity
3. Cleanliness.

4.5.2.3.2 Propellant for Thruster qualification

- a. Thruster qualification firing tests shall use the same propellant grade as the one selected for flight.

4.5.3 Sizing

- a. The sizing process shall begin with a definition of the life phases of each subsystem or component, including at least:

1. Pressure cycles combined with temperature cycles
2. Propellant, pressurant and leakage budgets
3. Establishment of the operational envelope
4. Minimum and maximum electrical supply voltages
5. Interfaces with GSE functions
6. Evolution of the operational conditions.

- b. The sizing process shall demonstrate margins based on:

1. Safety
2. Reliability requirements established by the customer

3. Industry and launch authorities, or agencies operational constraints
 4. Thruster performance efficiency
 5. Plume effects
 6. Modelling errors and uncertainties.
- c. Pressurant, propellant and contaminants budgets shall include:
1. Their impact on lifetime
 2. Variation of performance during lifetime
 3. Quantity for deorbiting
 4. Residuals.

4.5.4 Design development

4.5.4.1 General

- a. The development shall allow for an incremental verification at component or block level, if a fully representative functional test (i.e. hot firing and gravity-dependent functions) cannot be performed after the integration of the system components on the spacecraft.
- b. If the flight version of the system is divided into independent blocks, they should be separated by safety barriers such as pyrovalves, latch valves or burst membranes.

4.5.4.2 Development tests

- a. Development tests of each block should be defined to represent the conditions foreseen during the operation of the complete system.
- b. At least the following characteristics of the propellant feed system shall be determined by hydraulic tests:
 1. mass flow rate;
 2. dynamic and static pressure;
 3. temperature;
 4. response time.
- c. The testability at integrated spacecraft level and the ability to return after test to safe and clean conditions shall be demonstrated for each of the system blocks.
- d. Design and procedures shall be defined according to 4.5.4.2c.

4.5.5 Contamination

4.5.5.1 External contamination

- a. The thruster design, layout and orientation should prevent contaminant deposition on elements sensitive to contamination identified in clause 4.3.5a.

NOTE Contaminants deposition on sensitive elements, such as solar panels, star trackers, and optics, depends on the propellants used, the thruster characteristics, the layout of the propulsion system, the thruster orientation and the thruster duty cycle.

- b. The potential hazard of contamination and the expected level of contamination due to thruster exhaust shall be included in the plume analysis.

NOTE See clause 4.3.5c.

4.5.5.2 Internal contamination

- a. The propulsion system shall be designed to avoid the effects of internal contaminants, including propellant vapours, by:
1. Preventing intrusion, internal generation and circulation of contaminants.
 2. Preventing or controlling accumulation of contaminants throughout the various parts of the system.
 3. Preventing accumulation of contaminants during the various steps of production, verification and operation of the system.

NOTE 1 The presence of contaminants inside the propulsion system can lead to the loss of performance of some components or even to catastrophic failures.

NOTE 2 For example, propellant vapours can be considered as contaminants in a pressurisation system.

- b. The expected maximum level of contaminants inside the propulsion system shall be specified.
- c. The propulsion system design shall conform to the expected maximum level of contaminants.

4.5.6 Draining

- a. The system design shall allow for on-ground draining.
- b. The location of fill-and-drain valves and piping layout shall:
1. Prevent trapping of liquid in the system by on-ground draining.
 2. Prevent contact between dissimilar fluids.
 3. Allow purging of the system after draining.