

BS EN 16603-35-06:2014



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Space engineering — Cleanliness requirements for spacecraft propulsion hardware

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its secretary.

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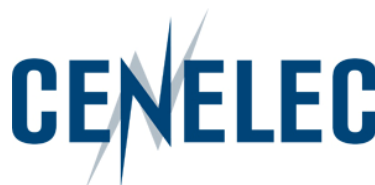
Raumfahrttechnik - Sauberkeitsanforderungen für die Antriebstechnik von Raumfahrzeugen

This European Standard was approved by CEN on 1 March 2014.

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Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (EN 16603-35-06:2014) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN.

This standard (EN 16603-35-06:2014) originates from ECSS-E-ST-35-06C rev.1.

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of an identical text or by endorsement, at the latest by March 2015, and conflicting national standards shall be withdrawn at the latest by March 2015.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 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 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.

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Scope

ECSS-E-ST-35-06 belongs to the Propulsion field of the mechanical discipline, and concerns itself with the cleanliness of propulsion components, sub-systems and systems

The standard

- defines design requirements which allow for cleaning of propulsion components sub-systems and systems and which avoid generation or unwanted collection of contamination,
- identifies cleanliness requirements (e.g. which particle / impurity / wetness level can be tolerated),
- defines requirements on cleaning to comply with the cleanliness level requirements, and the requirements on verification,
- identifies the cleanliness approach, cleaning requirements, (e.g. what needs to be done to ensure the tolerable level is not exceeded, compatibility requirements),
- identifies, specifies and defines the requirements regarding conditions under which cleaning or cleanliness verification takes place (e.g. compatibility, check after environmental test).

The standard is applicable to the most commonly used propulsion systems and their related storable propellant combinations: Hydrazine (N_2H_4), Mono Methyl Hydrazine ($\text{CH}_3\text{N}_2\text{H}_3$), MON (Mixed Oxides of Nitrogen), Nitrogen (N_2), Helium (He), Propane (C_3H_8), Butane (C_4H_{10}) and Xenon (Xe).

This standard is the basis for the European spacecraft and spacecraft propulsion industry to define, achieve and verify the required cleanliness levels in spacecraft propulsion systems.

This standard is particularly applicable to spacecraft propulsion as used for satellites and (manned) spacecraft and any of such projects including its ground support equipment.

External cleanliness requirements, e.g. outside of tanks, piping and aspects such as fungus and outgassing are covered by ECSS-Q-ST-70-01.

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

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.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system — Glossary of terms
EN 16603-35	ECSS-E-ST-35	Space engineering — Propulsion general requirements
EN 16602-40	ECSS-Q-ST-40	Space product assurance — Safety
EN 16602-70-01	ECSS-Q-ST-70-01	Space product assurance — Cleanliness and contamination control.
EN 16602-70	ECSS-Q-ST-70	Space product assurance — Materials, mechanical parts and processes
	ISO 2210:1972	Liquid halogenated hydrocarbons for industrial use—Determination of residue on evaporation
	ISO 5789:1979	Fluorinated hydrocarbons for industrial use — Determination of non-volatile residue
	ISO 5884:1978	Aerospace — Fluid systems and components — Methods for system sampling and measuring the solid particle contamination of hydraulic fluids
	ISO 14951-3:2000	Space systems — Fluid characteristics — Part 3: Nitrogen
	ISO 14951-4:2000	Space systems — Fluid characteristics — Part 4: Helium
	ISO 14951-10:2000	Space systems — Fluid characteristics — Part 10: Water
	ISO 14952-3:2003	Space systems — Surface cleanliness of fluid systems — Part 3: Analytical procedures for the determination of non-volatile residues and particulate contamination

	ASTM D257(99) 2005	Standard Test Method for DC Resistance or Conductance of Insulating Materials
	ASTM D329 10 Dec 2002	Standard specification for Acetone
	ASTM D740 15 May 2005	Standard specification for Methyl Ethyl Ketone
	ASTM D770-05 15 May 2005	Standard specification for Isopropyl Alcohol
	ASTM D1152 1 Apr 2006	Standard specification for Methanol (Methyl Alcohol)
	ASTM D1293 10 Dec 1999	Standard test methods for pH of water
	ASTM D4376	Standard specification for vapor-degreasing grade Perchloroethylene
	MIL-PRF-27415B 8 Feb 2007	Performance specification, propellant pressurizing agent, Argon
	O-E-760D 28 May 1987	Federal specification
	SEMI C47-0699 May 1999	Guideline for Trans 1,2 Dichloroethylene

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 Terms specific to the present standard

3.2.1 accuracy

measure of how close a value is to the “true” value

3.2.2 blank

result for an analytical sample of the virgin test fluid prior to use in performing a cleanliness verification test

3.2.3 cleanliness verification

activity intended to verify that the actual cleanliness conditions of an item are in conformance with the applicable specification

3.2.4 condensable hydrocarbon

hydrocarbon capable of going from a gaseous to a liquid or solid state at ambient temperature and pressure

3.2.5 crazing

creating microvoids in glassy thermoplastic polymers preceding the formation of cracks

3.2.6 critical surface

any surface of an item that contacts the service medium

NOTE Examples of service media are propellants and pressurants.

3.2.7 dewar

double-walled vessel with the annular space between the walls evacuated to provide insulation

3.2.8 dew point

temperature at which condensation of water vapour takes place at prevailing pressure

NOTE The prevailing pressure is usually atmospheric pressure.

3.2.9 fibre

flexible structure having a length-to-width ratio of 10 to 1 or greater

NOTE 1 A fibre is considered to be a particle, see clause 3.2.14.

NOTE 2 The size of a fibre is its maximum length.

3.2.10 field cleaning

processes of pre-cleaning and precision cleaning of components, subsystems and systems which cannot be processed in a controlled environment such as a clean room

3.2.11 generally clean

free from manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination based on visual examination

3.2.12 high-efficiency particulate air filter

filter that is at least 99,97 % efficient by volume on 0,3 μm particles

3.2.13 non-volatile residue

soluble or suspended material and insoluble particulate matter remaining after temperature-controlled evaporation of a volatile liquid

NOTE See also clause 6.2.4.3

3.2.14 particle

unit of solid matter with observable size

NOTE 1 Various methods for defining its size may be used and are dependant upon the measurement technique.

NOTE 2 For the manual method the apparent maximum linear dimension of a particle in the plane of observation as observed with instruments such as optical, electron, or atomic force microscopes is the particle size.

NOTE 3 For the automatic method, the equivalent diameter of a particle detected by automatic instrumentation is the particle size.

NOTE 4 The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured.

NOTE 5 A fibre is considered a particle, see clause 3.2.9.

3.2.15 passivation

process by which a corrosion-resistant layer is formed on a metal surface by submersing the surface in an acid solution

3.2.16 pickling

chemical or electrochemical process by which surface oxides are removed from metals

3.2.17 precision cleaning

cleaning process used to achieve cleanliness levels more stringent than visibly clean

3.2.18 pre-cleaning

cleaning process normally used to achieve the visibly clean cleanliness level

3.2.19 reversion

decrease in viscosity, strength, or in rubber modulus due to heating or overworking, resulting in a tacky and soft material

3.2.20 silting

accumulation of particles of sufficient quantity to cause a haze or obscuring of any portion of a filter membrane when viewed visually or under 40-power maximum magnification

3.2.21 test fluid

specified fluid that is utilized to determine the fluid system wetted-surface cleanliness level

3.2.22 threshold limit value

maximum average daily dosage, based on an 8-h day, 5-day week, to which an average worker may be exposed to hazardous chemicals without harmful effect

NOTE 1 The TLV is a time-weighted average concentration.

NOTE 2 The TLV is normally expressed in parts of the gas or vapour in micro litres per litre.

3.2.23 visibly clean

absence of surface contamination when examined with a specific light source, angle of incidence, and viewing distance using normal or magnified vision up to $\times 20$

3.2.24 visibly clean plus ultraviolet

cleaning level that is visibly clean and also meets the requirements for inspection with the aid of an ultraviolet light of wavelength 250 nm to 395 nm

3.2.25 volatile hydrocarbon

hydrocarbon capable of going from liquid or solid to a gaseous state at ambient temperature and pressure

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
CC	cleanliness certificate
CRA	cleaning requirement analysis
CTS	cleaning technique selection
GC	generally clean
HEPA	high-efficiency particulate air filter
HFE	hydro fluor ether (Per fluoro-n-butyl methyl ether)
IPA	isopropanol
MAIT	manufacturing, assembly, integration and test
MEK	methyl ethyl keton
MS	mass spectroscopy
NVR	non-volatile residue
ppmv	parts per million, volumetric
TLV	threshold limit value
US	ultra sonic
VC	visibly clean
VC + UV	visibly clean plus ultraviolet

3.4 Symbols

Symbol	Meaning
d_p	mean pore diameter of a filter

Cleanliness requirements

4.1 General

- a. This standard shall only apply to propulsion systems using Hydrazines, MON, Propane, Butane, Nitrogen, Helium, Xenon as propellants.
- b. Cleanliness assurance precautions and features shall be specified and incorporated in the hardware at the design phase.

NOTE In propulsion systems cleanliness is a major requirement to avoid loss of function and performance.

- c. Cleanliness verification shall be applied at progressive MAIT stages in the process.
- d. The hardware shall be designed to enable post-build cleaning and cleanliness verification.
- e. Operation and use shall not generate or release contamination.
- f. A cleanliness verification should be performed successively at component, sub-system and system level prior to a blind-end close-out.
- g. Cleanliness Particle Count levels shall be to a lower required class or subclass at the early hardware build and verification stages, than the final product.

NOTE 1 This allows final system-level cleanliness to be achieved.

NOTE 2 See Table 4-1: for cleanliness classes and subclasses.

- h. During the design phase the necessity of cleanliness verification shall be assessed.

NOTE 1 This applies from components to the design of systems, and to operations as not to generate contamination and to enable cleaning.

NOTE 2 Figure B-1 of ECSS-Q-ST-70-01 gives an overview of space system cleanliness requirements organized in a cleanliness control flow chart.

- i. Compatibility of cleaning fluids with the propulsion system materials and propellants shall be established in conformance with Annex A.

NOTE 1 For efficient cleaning chemical compounds like alkaline and acid cleaners are required.

NOTE 2 Related requirements are specified in ECSS-E-ST-35-10, 'Known incompatibilities' concerning compatibility testing for liquid propulsion components, subsystems and systems.

- j. All components, subsystems, systems or related equipment for use in ground support equipment and spacecraft requiring cleaning shall be
 - 1. cleaned to the specified cleanliness level, in conformance with the CRA produced in conformance with Annex A,
 - 2. inspected in conformance with Annex B.
- k. The results of 4.1j shall be reported in conformance with Annex C.
- l. Any component, subsystem or system that can be damaged during cleaning shall be:
 - 1. protected or removed before cleaning;
 - 2. cleaned as a separate item in conformance with the CTS produced in conformance with Annex B.
- m. Cleaning or disassembly operations on precision components shall be performed only by personnel who have been trained and certified to perform these functions.

4.2 Design requirements

4.2.1 General

- a. Designs shall be such that the product
 - 1. avoids contamination and
 - 2. allows for cleaning and drying.
- b. Cleanliness classes shall be established in conformance with Annex A, to apply to propulsion components, subsystems and systems.

4.2.2 Components

4.2.2.1 Tanks

- a. Tank internal structures shall not shed particles during operation.
- b. Tank internal structures shall allow for draining and cleaning.

NOTE Examples of such structures are diaphragms, bladders, baffles, and surface tension screens.

4.2.2.2 Tubing and manifolds

- a. Tubings and manifolds should avoid stepped diameter transitions that create turbulence or flow separation.

NOTE Turbulent flows and wakes can cause particle deposition.

- b. Tubings and manifolds should avoid blind holes and dead ends,
- c. Tubings and manifolds shall avoid internal threads.

NOTE The risk of contamination is increased with the number of screw joints.

4.2.2.3 Valves and regulators

- a. Solenoid valves should use flexure guided armatures.

NOTE Sliding surfaces can jam or generate particles.

- b. Valve or regulator function and performance shall be independent from lubrication on critical surfaces.

- c. Fluid paths should be smooth, avoiding stepped transitions.

NOTE This is to avoid entrapment of contamination.

- d. Valve or regulator parts and assembled parts should allow for ultrasonic cleaning, in conformance with the CTS produced in conformance with Annex B.

- e. Protective filters shall be dimensioned in conformance with the CRA produced in conformance with Annex A, such that the selected filtration rate does not allow particles exceeding a specified size, to pass, thereby degrading function and performance.

- f. Reference ports on regulators shall be protected by filters.

- g. In conformance with the CRA produced in conformance with Annex A, protective filters shall be dimensioned such that the specified accumulated contamination causes no pressure drop exceeding the requirement.

- h. Valve- or regulator-poppet design shall avoid entrapment of contamination.

- i. A valve or regulator assembly should allow for the integration of protective filters after the final cleaning of the unit has been performed and verified in conformance with the CTS produced in conformance with Annex B.

- j. Valves and regulators subject to reverse flow shall incorporate an outlet filter.

- k. Valves and regulators shall avoid cavities, if not functionally required.

- l. Valves and regulators shall not generate contamination, exceeding the specified level, when exposed to the specified environmental and functional tests.

NOTE 1 E.g. during dry cycles.

NOTE 2 Sliding armatures can generate contamination.

NOTE 3 Sliding armatures are susceptible to jamming and wear.

4.2.2.4 Filters

- a. Filters shall not shed particles, exceeding the specified level, during operation and environmental testing.

4.2.2.5 Instrumentation

- a. Sensors introducing cavities shall allow for cleaning by a flushing lance.

NOTE See Annex B.

- b. Cavities or dead end tubing shall allow for thermal and vacuum drying.

NOTE See Annex B.

4.2.2.6 Injectors

- a. The deposition of NVR in capillary tubes and injector bores during operation shall be analysed and reported.

NOTE 1 E.g. during pulse mode.

NOTE 2 See Annex A.

4.2.2.7 Thrust chambers

- a. The deposition of NVR on catalyst beds shall be analysed and reported.

NOTE See Annex A.

4.2.3 System

- a. The system shall allow for ground draining of simulation fluids and of propellants.
- b. Systems requiring cleaning and cleanliness verification shall have no protective filters at fill and drain valves or test ports.
- c. Filtration rate and capacity requirements shall include the flight operation and the contamination introduced by integration and testing at higher build level.

NOTE See Annex A.

- d. The integration of filters should be performed after final cleaning and verification of the related subsystems.

NOTE See Annex B.

- e. Line replaceable components shall be protected by built-in filters.
- f. The system design should enable flow-down cleanliness verification (see clause 4.1g).

4.2.4 Ground support equipment (GSE)

- a. Connect/disconnect interfaces shall be protected from contamination by filters or by procedures

NOTE E.g. purge flow during connection / disconnection.

- b. GSE protective filters shall be at the interfacing point to the flight hardware.
- c. The GSE shall provide for draining and drying interfaces

NOTE E.g. back flush.

- d. The GSE shall provide sampling interfaces and sampling equipment to verify cleanliness.
- e. Filtration of simulation fluids or propellants shall be performed to a cleanliness class equal or better than the propulsion system requirements.

NOTE See Annex A.

4.3 Manufacturing

4.3.1 General

- a. Manufacturing aspects that affect the selection of cleaning techniques shall be reported in conformance with Annex B.

4.3.2 Manufacturing processes

- a. ECSS-Q-ST-70-01 requirements for 'Manufacturing' and 'Assembly and integration' shall apply.
- b. The required proof pressure testing shall be performed after cleaning processes that affect material properties

NOTE E.g. after acid treatment.

4.3.3 Machined parts

- a. Machined parts shall be cleaned as specified for the subsequent manufacturing operations.

NOTE This is also to achieve the final cleanliness level.

- b. Machined parts shall be free of burrs.

NOTE For large items such as diaphragms and bladders, special cleaning procedures can be necessary.

4.3.4 Tubing and manifolds

- a. Tubing, manifolds and transition joints shall be free of burrs, maintaining sharp edges for welding.
- b. Tubing, manifolds and transition joints shall have passed all contaminating handling steps before final cleaning, e.g. bending, flaring, cutting to length and contaminating inspections.

- c. Light oxide films, shall be removed by validated processes, e.g. brushing with a clean stainless steel wire brush, glass blasting (except for flow paths), draw filing, acid pickling.
- d. Grinding shall not be performed on tube end interface surfaces that are subject to welding.

NOTE Debris from the grinding wheel can get embedded in the metal surface. This has been known to cause weld problems due to contamination embedded at the interface during welding.

- e. The area to be treated by acid pickling shall be degreased with non-halogenated solvents.
- f. Component interiors shall be protected by internally plugging the tubing stud in case of acid pickling.

NOTE For example, valves.

- g. Water flushing shall be used to neutralize the pickling solution.
- h. Tubing and manifolds shall be dried by gas purging.
- i. Tubing shall be protected from contamination by oxidation during welding.
- j. Welding shall avoid generating weld sputter in components, subsystems and system.
- k. To protect stainless steel against external corrosion (e.g. after welding) pickling and passivation shall be performed.

NOTE Titanium tubing and manifolds can be pickled in a suitable acid and flushed with de-mineralised water to allow surface natural re-passivation.

- l. Installation of a seal shall not introduce contamination into the system.

NOTE E.g. installation of O-rings.

- m. Abrasion and surface damage of a seal during integration shall be avoided.

NOTE E.g. by using application compatible lubricants, masking of sharp edges.

- n. The lubricant of mechanical joints shall not be introduced into the critical surface area or come into contact with propellants, pressurants or simulation fluids.
- o. The joining process shall not introduce contamination into the critical surface area or bring contaminants into contact with propellants, pressurants or simulation fluids.
- p. For repair and trimming-to-length clause 6.3.4 shall apply

4.3.5 Components

- a. Components with liquid retaining cavities or capillary structures used for gas applications shall be
 - 1. flushed with liquids only at component level,
 - 2. verified to be dry.

NOTE E.g. pressure regulators, non return and relief valves.

- b. Joining components to cleaning facilities shall not cause damage to interfaces.
- c. Assembly of components (e.g. orifices, valve seats) shall be performed under a controlled environment in conformance with the requirements for "Cleanrooms" in ECSS-Q-ST-70-01F, and the cleanliness requirements of the component.
- d. Hardware shall not be exposed to environments causing chemical contamination.

NOTE This can give rise to corrosion or chemical reactions in a later stage of life.

- e. If not protected by specific means to avoid internal contamination, assembled components shall be tested in a controlled environment in conformance with the requirements for cleanrooms in ECSS-Q-ST-70-01 and the cleanliness requirements of the component.
- f. It shall be determined which environmental classes apply to 4.3.5c and 4.3.5e.

NOTE See Annex A.

- g. Procedures shall ensure that components that can be damaged or contaminated by reverse flow are not flushed or purged in opposite direction, neither during component operation, nor during subsystem or system operation.
- h. For filters, procedures shall ensure that the last flushing operation at component level is performed in the nominal direction.
- i. Tanks with built in propellant management devices shall have undergone all individually required precision cleaning processes and verification prior to final welding.
- j. No introduction or formation of contaminants during subsequent assembly and operations shall take place.

NOTE E.g. introduction or formation of weld spatter.

- k. Valves and regulators that cannot be dried after liquid flushing shall be cleaned with either:
 - 1. Nitrogen in conformance with ISO 14951-3 Type A, filtered through a filter with $d_p \leq 2 \mu\text{m}$, or
 - 2. Helium in conformance with ISO 14951-4 Type A, filtered through a filter with $d_p \leq 2 \mu\text{m}$, or

3. Argon in conformance with MIL-PRF-27415B grade B, filtered through a filter with $d_p \leq 2 \mu\text{m}$.
- l. For the purpose of cleaning, the non-single-use valve or regulator shall be operated during flushing or purging.
- m. Purging or flushing of thrusters shall take the thrusters characteristics into account.

NOTE 1 Monopropellant thrusters with catalytic beds have limitations regarding flushing liquids, gas flow rates and pressure differentials.

NOTE 2 Actuation of a flow control valve with gas flow is subject to limitations to avoid overheating of the valve.

4.3.6 Subsystems and systems

- a. Subsystems incorporating components that constrain flushing or purging shall be built up allowing for in-process cleaning in accordance with clause 4.1c.
- b. Subsystems with limited access and requiring flushing or purging shall be fitted with test ports.
- c. Closed or protected subsystems and systems shall be handled in conformance with the ECSS-Q-ST-70-01, class M6.5 environment.
- d. Open subsystems and systems shall be handled in a specified environment equal to or better than ECSS-Q-ST-70-01 class M6.5.
- e. It shall be determined which environmental class applies to requirement 4.3.6d.

NOTE See Annex A.

- f. Procedures shall be established to avoid contamination of the subsystem or system in case of component exchange.

4.3.7 Final rinsing solutions

- a. The final rinsing solution shall meet or exceed the cleanliness requirements for which they are intended.
- b. The rinsing liquid shall meet the requirements of clauses 4.4.4a, 4.4.4b, 4.4.4c, and 4.4.4h.
- c. If the final rinsing is not compatible with the operational fluid in the system being cleaned, it shall be demonstrated that subsequent operations remove any residual rinsing solutions.

NOTE E.g. if IPA or ethanol only for the fuel system, not for the oxidizer system.