ICS 49.140 TECHNICKÁ NORMALIZAČNÁ INFORMÁCIA Január 2022

TNI	**Kozmická technika** **Príručka pre techniku vysokého napätia a navrhovanie**	**TNI CEN/CLC/TR 17603-20-05** 31 0540

Space engineering - High voltage engineering and design handbook

Táto technická normalizačná informácia obsahuje anglickú verziu CEN/CLC/TR 17603-20-05:2021.
This Technical standard information includes the English version of CEN/CLC/TR 17603-20-05:2021.

Táto technická normalizačná informácia bola oznámená vo Vestníku ÚNMS SR č. 12/21

134164

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/CLC/TR 17603-20-05

August 2021

ICS 49.140

English version

Space engineering - High voltage engineering and design handbook

Ingénierie spatiale - Manuel d'ingénierie et de conception haute tension

Raumfahrttechnik - Handbuch für Hochspannungstechnik und Design

This Technical Report was approved by CEN on 14 June 2021. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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

CEN-CENELEC Management Centre:
Rue de la Science 23, B-1040 Brussels

Ref. No. CEN/CLC/TR 17603-20-05:2021 E

Table of contents

Figures

Tables

European Foreword

This document (CEN/CLC//TR 17603-20-05:2021) has been prepared by Technical Committee CEN/CLC/JTC 5 "Space", the secretariat of which is held by DIN.

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 16603-20.

This Technical report (TR 17603-20-05:2021) originates from ECSS-E-HB-20-05A.

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 TR covering the same scope but with a wider domain of applicability (e.g.: aerospace).

Introduction

The subject of high voltage engineering and design has been part of the spacecraft design process since the early times of spaceflight.

This was due to need for high voltage power conditioners being a key element of communication links. The relate expertise was built up in Europe in the decade of the 1980 with the support of the development of modern Electronic Power Conditioners (EPC's), to operate Travelling Wave Tube Amplifiers for telecommunication satellites and for high power radar applications.

In 1989 ESA launched its first high power radar for earth observation onboard the ERS-1 (European Remote Sensing Satellite), achieving a technology for 15 kV – 17 kV in space.

Today typically between some ten and over hundred EPC's with operating voltages of 5 kV - 8 kV are placed on many of the telecommunications satellites.

Several space borne radars with travelling wave tubes and klystrons are in orbit using voltage up to 20 kV. Various detectors for various kind of space environment with voltage between a few hundred volts and up to 30 kV are used in many missions, high power lasers up to 150 kV were studied, and even some experiments onboard the International Space Station using fancy high voltage sources.

The latest trend is the increasing use of electric propulsion for satellites dealing with supply voltage in the range between a few hundred volts and above 10 kV. High voltage related anomalies have been observed only a few times, some in the early years of building up experience, some also later, especially when new developments were done with new teams inexperienced in the field.

A need was identified for a standard already in the early years of the space flight, the US air force and NASA presented a series design and test handbook in the 1970's and 1980's. In Europe, ESA started discussing a draft standard with industry: the PSS-02-303 draft 2 from 1992 "Requirements for High Voltage Transformer and Components used in Electronic Power Conditioners for ESA Space Systems" this became a quasi standard reference in many space projects, even if it was never formally released. The growing diversity of high voltage application gave finally the urgency to make a new approach for standardization. The discussion started in 2007 with ECSS who led to the conclusion, that a standard would not satisfy the immediate needs for projects, as it would be too wide to cover the diverse applications and also would not be suitable to transfer the "know-how" of high voltage engineering and design. Therefore it was decided to produce a handbook to give a broad scope of knowledge and recommendations for design and test of high voltage equipment and components.

This document aims to satisfy these needs and provides a detailed view of high voltage knowledge aspects as well as giving a guideline to identify suitable design rules.

Proper design of high voltage effects of these processes is part of the system engineering process as defined in ECSS-E-ST-20, where only a small subset of high voltage requirements is given.

For new projects involving high voltage equipment and design it is useful to provide this handbook as a reference to generate suitable requirements specific to the targeted high voltage application.

Chapter 7 of this document gives some "best practice" statements.

Only a smart answer can be given to the definition of the range of voltages which should be considered as high voltages: The ECSS-E-ST-20C states for the definition of a high voltage "AC or DC voltage at which partial discharges, corona, arcing or high electrical fields can occur". For space environment this can occur ". This in fact can already appear at 60 V – 80 V if a low pressure environment in an inert gas provides a critical pressure for "Paschen Breakdown". Under air (N_2/O_2 mixtures) this can occur for voltage of above 300 V.

1 Scope

This Handbook establishes guidelines to ensure a reliable design, manufacturing and testing of high voltage electronic equipment and covers:

- Design
- Manufacturing
- Verification/Testing

of equipment generating, carrying or consuming high voltage, like: high voltage power conditioner, high voltage distribution (cables and connectors).

This Handbook is dedicated to all parties involved at all levels in the realization of space segment hardware and its interface with high voltage for which ECSS-E-ST-20C is applicable.

This handbook sets out to:

- summarize most relevant aspects and data of high voltage insulation
- provide design guidelines for high voltage insulation
- provide design guidelines for high voltage electronic equipment
- give an overview of appropriate high voltage test methods
- establish a set of recommendations for generation design and verification rules and methods
- provide best practices

Applicability is mainly focused on power conditioning equipment but may be also applicable for all other high voltage electric and electronic power equipment used on space missions, except items of experimental nature.

2 References

EN Reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS System – Glossary of terms
EN 16603-10-02	ECSS-E-ST-10-02	Space engineering - Verification
EN 16603-10-03	ECSS-E-ST-10-03	Space engineering - Testing
EN 16603-10-04	ECSS-E-ST-10-04	Space engineering - Space environment
EN 16603-20	ECSS-E-ST-20	Space engineering - Electrical and electronic
EN 16603-20-01	ECSS-E-ST-20-01	Space engineering - Multipactor design and test
EN 16603-20-06	ECSS-E-ST-20-06	Space engineering - Spacecraft charging
EN 16603-32	ECSS-E-ST-32	Space engineering - Structural general requirements
EN 16602-30-11	ECSS-Q-ST-30-11	Space product assurance - Derating – EEE components
EN 16602-70-10	ECSS-Q-ST-70-10	Space product assurance - Qualification of printed circuit boards
EN 16602-70-11	ECSS-Q-ST-70-11	Space product assurance - Procurement of printed circuit boards
EN 16602-70-71	ECSS-Q-ST-70-71	Space product assurance - Data for selection of space materials and processes
-	ESA SP-398 (May 1997)	Power supply and control unit (PCSU) for radio frequency ion thrusters (RIT)" ESA, Proc. 2nd European Spacecraft Propulsion, Noordwijk, The Netherlands, 27-29 May 1997 (ESA SP-398), pp 643-648.
-	ESA SP-555 (June 2004)	The Power Control Unit for the Propulsion Engine of GOCE Program, Tato, C.; Palencia, J.; De la Cruz, F., 4th International Spacecraft Propulsion Conference, 2-4 June 2004 Chia Laguna (Cagliari), Sardinia, Italy
-	ESA SP-569 (June 2004)	The T5 Ion Propulsion Assembly for Drag Compensation on GOCE, Proceedings of the Second International GOCE User Workshop
-	AIAA 2005-4224 (2005)	First Test Results of the 1 to 15 kW Coaxial HEMP 30250 Thurster, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 10 - 13 July 2005, Tucson, Arizona
-	AIAA 2006-4476 (2006)	High Power HEMP-Thruster Module, Status and Results of a DLR and ESA Development Program, 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 9 - 12 July 2006, Sacramento, California

EN Reference	Reference in text	Title
-	AIAA 2006-4825 (2006)	Micro-Newton Electric Propulsion Subsystems for Ultra-Stable Platforms, 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 9 - 12 July 2006, Sacramento, California
-	AIAA 2006-5172 (2006)	Theoretical Study of the Breathing Mode in Hall Thrusters, 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 9 - 12 July 2006, Sacramento, California
-	AIAA 2007-5215 (2007)	Generic High Voltage Power Supply – Next Generation, 43rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 8 - 11 July 2007, Cincinnati, OH
-	AIAA 2007-5250 (2007)	RIT-µX - High Precision Micro Ion Propulsion System based on RF-Technology, 43rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 8 - 11 July 2007, Cincinnati, OH
-	AIAA 2008-4632 (2008)	A model for the active control of low frequency oscillations in Hall thrusters, 44th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 21 - 23 July 2008, Hartford, CT
-	ASTM-D-150 (2011)	Standard Test Methods for AC Loss :Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
-	ASTM D-2214 (2002)	Standard Test Method for Estimating the Thermal Conductivity of Leather with the Cenco-Fitch Apparatus
-	ASTM-D-2240 (2010)	Standard Test Method for Rubber Property: Durometer Hardness
-	ASTM-D-638 (2010)	Standard Test Method for Tensile Properties: of Plastics
-	ASTM-D-695 (2010)	Standard Test Method for Compressive: Properties of Rigid Plastics
-	ASTM-D-794 (1993)	Practice for Determining Permanent Effect of Heat on Plastics
-	ASTM-E831 (2006)	Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
-	Cygan P and Loghari J R (October 1990)	Models for insulation aging under electrical and thermal multistress, IEEE Transactions on Electrical Insulation, Vol 25, pg. 923-934
-	ESCC 3001 (October 2002)	Capacitors, Fixed, Ceramic Dielectric: Types I and II, Generic Specification
-	ESCC 3006 (October 2002)	Capacitors, Fixed, Film, Dielectric: Generic Specification

EN Reference	Reference in text	Title
-	ESCC 3901 (October 2002)	Wires and Cable, Electrical, 600V: Low Frequency, Generic Specification
-	E. Bourguignon, T. Scalais, J. Thomas (June 2004)	High Power Processing Unit for Stationary Plasma Thruster, Journal: Proc. 4th International Spacecraft Propulsion Conference (ESA SP-555). 2-4 June, 2004, Chia Laguna (Cagliari), Sardinia, Italy. p.65.1 ff
-	F. Boer (2004)	BN100 filler technology, ARTHE Engineering Solutions S.R.L., 2004
-	GSFC-S-311-P-796C (April 2007)	Resistors, “Matched-Pair”,Low TC, Precision, RadialLead (Caddock Type TK)
-	IEC 60216-1 ed5.0 (July 2007)	Electrical insulating materials - Properties of thermal endurance, Part 1: Ageing procedures and evaluation of test results
-	J. C. Halpin (1985)	AVIP Air Force thrust for reliability”, Institute of Environmental Sciences, Annual Technical Meeting, 31st, Las Vegas, NV, April 30-May 2, 1985, Proceedings (A86-23001 09-38). Mount Prospect, IL, Institute of Environmental Sciences, 1985, p. 206-218
-	J.-P. Crine (October 2002)	Ageing and Polarization Phenomena in PE under High Electrical fields, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 9, No. 5, pp. 697-703
-	J.L. Parpal, J.-P. Crine, C. Dan (April 1997)	Electrical Ageing of Extruded Dielectric Cables, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 4, No. 2, pp. 197-209, 1997
-	L. Ceruti, M. Magnifico (May 2005)	Power Control Unit for μN Propulsion Subsystem, Proc. Seventh European Space Power Conference, Stresa, Italy, 9-13 May 2005, Proceeding ESA SP-589
-	MIL-PRF-19500P (October 2010)	Performance Specification: Semiconductor Devices, general specification for
-	MIL-R-39008C (August 1990)	Military Specification: Resistor, Fixed, Composition (Insulated), established reliability, general specification
-	NASA-STD-8739.4 (March 2011)	Crimping, interconnecting cables, harnesses, and wiring (Baseline w/ Change 6)
-	R.V. Latham (1996)	High Voltage Vacuum Insulation, Academic Press, London, San Diego, 1996, Section 8
-	T.W. Dakin (January1948)	Electrical Insulation Deterioration Treated as Chemical Rate Phenomenon, AIEE Transactions, Vol. 67, pp. 113-122.
-	T.W. Dakin (1960)	Electrical Insulation Deterioration, Electrotechnology, Vol. 3, pp. 129-13.

EN Reference	Reference in text	Title
-	ESA contract 18697/04/NL/MV (July 2005)	Quick maintenance for high voltage equipment with the new not toxic boron nitride powder (BN100) superior thermal conductive and lightweight filler