BS ISO 26871:2020

BSI Standards Publication

Space systems — Explosive systems and devices

Documents
Document Sharing Hub

Full document details: BS ISO 26871:2020

National foreword

This British Standard is the UK implementation of ISO 26871:2020.

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 committee manager.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 02975 8

ICS 49.140

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2020.

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS ISO 26871:2020

INTERNATIONAL STANDARD

ISO 26871

Second edition
2020-10

Space systems — Explosive systems and devices

Systèmes spaciaux — Dispositifs et equipements explosifs

Reference number
ISO 26871:2020(E)

Documents
Document Sharing Hub

© ISO 2020

Full document details: BS ISO 26871:2020

COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub

Full document details: BS ISO 26871:2020

Contents

Page

Foreword ... **v**

Introduction ... **vi**

1 Scope ... **1**

2 Normative references ... **1**

3 Terms, definitions, abbreviated terms and symbols ... **1**
3.1 Terms and definitions ... 1
3.2 Abbreviated terms ... 8
3.3 Symbols ... 10

4 Requirements ... **10**
4.1 General ... 10
4.1.1 Background information ... 10
4.1.2 Overview ... 10
4.1.3 Applicability ... 11
4.1.4 Properties ... 11
4.2 Design ... 11
4.2.1 General ... 11
4.2.2 Debris requirements ... 12
4.2.3 Reliability and confidence levels ... 13
4.2.4 Performance ... 13
4.2.5 Wanted and unwanted response ... 13
4.2.6 Dimensioning ... 13
4.3 Mission ... 16
4.4 Functionality ... 16
4.5 Safety ... 17
4.5.1 General ... 17
4.5.2 Prevention of unintentional function ... 17
4.6 Survival and operational conditions ... 18
4.7 Interface requirements ... 19
4.7.1 General ... 19
4.7.2 Functional ... 19
4.7.3 Internal ... 19
4.7.4 External ... 20
4.8 Mechanical, electrical, and thermal requirements ... 20
4.8.1 Mechanical ... 20
4.8.2 Electrical ... 21
4.8.3 Thermal ... 24
4.8.4 Status check ... 25
4.9 Materials ... 26
4.10 Production lot ... 27
4.11 Non-explosive components and equipment ... 27
4.11.1 Connectors ... 27
4.11.2 Wiring ... 27
4.11.3 Shielding ... 28
4.11.4 Faraday cap ... 28
4.11.5 Safety cap ... 28
4.11.6 Power ... 28
4.11.7 Arm plug receptacle ... 29
4.11.8 Safe plug ... 29
4.11.9 Arm plug ... 30
4.11.10 Test plug ... 30
4.11.11 Safe and arm device ... 30
4.11.12 Initiator harness connector ... 32
4.11.13 Initiator test substitute ... 32

AVA Documents
Document Sharing Hub

© ISO 2020 – All rights reserved

Full document details: BS ISO 26871:2020

4.12 Explosive components ... 32
4.12.1 General ... 32
4.12.2 Initiators, cartridges, detonators and packaged charges ... 33
4.12.3 Through-Bulkhead initiators ... 38
4.12.4 Integral initiator connectors ... 38
4.12.5 Transfer devices ... 39
4.12.6 Safe and arm devices containing explosive ... 40
4.12.7 Gas generators ... 41
4.12.8 Shaped charges ... 41
4.12.9 Expanding tube separation system ... 42
4.12.10 Distribution boxes ... 43
4.12.11 Explosive delays ... 44
4.13 Explosively actuated devices ... 45
4.13.1 General ... 45
4.13.2 Separation nuts and separation bolts ... 46
4.13.3 Pullers ... 47
4.13.4 Pushers (Thrusters) ... 48
4.13.5 Cutters ... 48
4.13.6 Pyro-valves ... 49
4.14 Items external to the flight equipment ... 50
4.14.1 GSE ... 50
4.14.2 Test equipment ... 50
4.14.3 Launch site ... 50
4.15 Verification ... 50
4.15.1 General ... 50
4.15.2 Inspection ... 50
4.15.3 Tests ... 51
4.15.4 Qualification and lot acceptance ... 53
4.16 Transport, facilities, handling and storage ... 56
4.16.1 General ... 56
4.16.2 Transport ... 56
4.16.3 Facilities ... 57
4.16.4 Handling and storage ... 57
4.17 In-service ... 58
4.17.1 Information feedback ... 58
4.17.2 Launch site procedures ... 58
4.17.3 Monitoring ... 58
4.18 Product assurance ... 58
4.18.1 General ... 58
4.18.2 Dependability ... 58
4.18.3 Assembly integration and tests ... 58
4.19 Deliverables ... 59

Annex A (normative) **Loads and factors of safety relationship** ... **61**

Annex B (normative) **Factors of safety** ... **63**

Annex C (informative) **Explosive component colour code** ... **64**

Annex D (informative) **Component qualification test levels to be customized to the space system considered** ... **65**

Annex E (informative) **Product user manual (PUM/UM) — DRD** ... **67**

Annex F (informative) **Safety data sheet** ... **73**

Bibliography ... **77**

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO 26871:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

— simplification for some requirements;

— updating terminology;

— introduction of a paragraph about debris issues.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

Introduction

0.1 Background

The evolution of this document is motivated by changes inputted by the last issue of 2 main mother documents[1],[2].

0.2 Tailoring

This document may be tailored, by the contractor, in consultation with the procuring authority, for the specific characteristics and constraints of a space project.

Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some cases, modification and addition (e.g., for manned spaceflight) of requirements in the standards.

However, the tailored requirements may achieve a level of verification equivalent to the baseline described herein. Rationale for each tailored requirement may be established. If the requirements in this document are not tailored by a contract, they stand as written.

This document will be updated and revised periodically, each five years as appropriate to incorporate technological advances and innovations as well as lessons learned.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

Space systems — Explosive systems and devices

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document specifies criteria and requirements for the use of explosive systems and explosive devices commonly used on spacecraft and other space products, including launch vehicles and space vehicle systems. It addresses the aspects of design, analysis, verification, manufacturing, operations and safety.

To the greatest extent possible, requirements from past and existing standards have been analyzed, selected and tailored to be incorporated herein. In addition, the requirements herein include those generated as a result of lessons learned from launch and space vehicle programs.

NOTE Specific requirements for man-rating are not addressed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14300-1, *Space systems — Programme management — Part 1: Structuring of a project*

ISO 24113, *Space systems — Space debris mitigation requirements*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
actuator
component (3.1.10) that performs the moving function of a mechanism

Note 1 to entry: An actuator can be either an electric motor, or any other mechanical (e.g. spring) or electric component or part providing the torque or force for the motion of the mechanism.

3.1.2
all-fire level
lowest level of the fire stimulus (including rise time, shape, duration), which results in initiation of a *first element (initiator)* (3.1.36) within a specific reliability and confidence level as determined by test and analysis

Note 1 to entry: The stimulus duration shall be compliant with the system.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

Note 2 to entry: The test sequence should be carried out at the lowest temperature of the operating range.

Note 3 to entry: The probability of functioning should be equal to or better than 0,999 at the 95 % confidence level.

3.1.3
armed
status of an explosive subsystem, when all the safety devices have been disabled and which is able to trigger

3.1.4
auto-ignition
spontaneous explosive reaction of *energetic materials* (3.1.19) in an explosively loaded device due to exposure to environments or interfacing materials

3.1.5
bridgewire
resistive element incorporated into the *first element* (3.1.30) that converts electrical energy into heat or shock to cause initiation of an explosive *charge* (3.1.8)

3.1.6
cartridge
explosive device designed to produce pressure for performing a mechanical function or actuate a mechanical device

Note 1 to entry: A cartridge is called an *initiator* (3.1.36) if it is the first or only explosive element in an *explosive train* (3.1.28).

3.1.7
catastrophic failure
failure which results in the loss of human life, mission or a major ground facility, or long-term detrimental environmental effects

3.1.8
charge
explosive (3.1.23) loaded in a *cartridge* (3.1.6), *detonator* (3.1.14) or separate container for use in an explosive device

3.1.9
closed bomb
fixed volume test chamber to measure output characteristics of pressure producing devices

3.1.10
component
set of materials, assembled according to defined and controlled processes, which cannot be disassembled without destroying its capability and which performs a simple function that can be evaluated against expected performance requirements

Note 1 to entry: The term “part” is preferred when referring to purely mechanical or explosive devices.

Note 2 to entry: The term “component” is preferred for EEE devices.

3.1.11
cook-off temperature
maximum temperature to which an explosively loaded device can be exposed for a period of one hour without reaction

Note 1 to entry: The determination of the cook-off temperature is time and application dependent.

3.1.12
deflagration
chemical decomposition propagating through the *explosive* (3.1.23) at a subsonic velocity

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

3.1.13
detonation
chemical decomposition propagating through the *explosive* (3.1.23) at a supersonic velocity such that a shock wave is generated

3.1.14
detonator
initiator (3.1.36) whose function is to transform external energy (e.g., mechanical, electrical, thermal) directly into a shock wave strong enough to detonate a secondary *high explosive* (3.1.34)

Note 1 to entry: Detonators are generally used to effect *detonation* (3.1.13) transfers within *explosive trains* (3.1.28).

3.1.15
duding
explosive *charge* (3.1.8) or *component* (3.1.10) that fails to fire or function upon receipt of the prescribed initiating stimulus, after an external effect (human failure, manufacturing failure, environmental, chemical, ageing, etc.)

3.1.16
electro-explosive device
EED
first element (3.1.30) of an *explosive train* (3.1.28): *initiator* (3.1.36) electrically actuated, which has a *bridgewire* (3.1.5) to transform electrical energy inputted into a reaction of the mixture used (e.g., *explosive* (3.1.23) or *pyrotechnics* (3.1.47))

Note 1 to entry: The output of the initiation is heat, shock or mechanical action, see 3.1.13.

3.1.17
electrostatic discharge
ESD
transfer of electrostatic *charge* (3.1.8) between objects at different potentials caused by direct contact or induced by an electrostatic field

3.1.18
end user
person who, or organization that, actually uses a product

Note 1 to entry: The end user may not to be the owner or buyer.

3.1.19
energetic material
material containing, an *explosive* (3.1.23), oxidizer, fuel or combination of them, that can undergo, contribute to, or cause rapid exothermic decomposition such as: combustion, *deflagration* (3.1.12) or *detonation* (3.1.13)

3.1.20
expanding tube separation system
separation system that emits no contamination and that includes detonating cord in a ductile metal tube and a structure containing geometrically controlled stress risers

3.1.21
exploding bridgewire device
EBW
high voltage device in which the *bridgewire* (3.1.5) explodes when functioned

3.1.22
exploding foil initiator
EFI
high voltage device that generates a supersonic flyer plate when functioned

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

3.1.23
explosive
material which is capable of undergoing an explosion when subjected to heat, impact, friction, *detonation* (3.1.13) or other suitable initiation

3.1.24
explosively actuated device
mechanism that converts the products of explosion (combustion, *deflagration* (3.1.12) or *detonation* (3.1.13)) into useful mechanical work

Note 1 to entry: Pyro-mechanisms and linear detonating separation devices are explosively actuated devices.

3.1.25
explosive component
any discrete item containing an explosive substance

3.1.26
explosive function
any function that uses energy released from explosive substances for its operation

3.1.27
explosive system
collection of all the *explosive trains* (3.1.28) on the *spacecraft* (3.1.60) or *launcher* (3.1.38) system, and the interface aspects of any on-board computers, launch operation equipment, ground support and test equipment and all software associated with *explosive functions* (3.1.26)

3.1.28
explosive train
ET
series of *explosive components* (3.1.25) that transfer explosive signal from the *first element* (3.1.30) to the final *explosively actuated device* (3.1.24)

3.1.29
extreme envelope
positive margin over the conditions of the qualification envelope

Note 1 to entry: The device or system design is based on the conditions that define the extreme envelope.

3.1.30
first element
initial element of an *explosive system* (3.1.27) that converts electrical, optical, or mechanical energy to explosive energy

3.1.31
fail operational
mission capable after one failure

3.1.32
fail safe
design property of a system/subsystem (or part of it), which prevents its failures from resulting in critical or catastrophic consequences (i.e. remain *safe* (3.1.50) after one failure)

Note 1 to entry: Maintaining safety following two independent failures is referred to “fail safe – fail safe”.

3.1.33
gas generator
explosive device wherein pyro *charge* (3.1.8), as a result of chemical reaction, is converted in gaseous products of reaction or exothermic output, or both

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

3.1.34
high explosive
HE
any chemical material in which the fuel and oxidizer are contained in the same molecule, the decomposition of which is a *detonation* (3.1.13)

3.1.35
hot bridgewire device
HBW
low voltage *EED* (3.1.16)

3.1.36
initiator
first explosive element in an *explosive train* (3.1.28) which, upon receipt of the proper mechanical, optical or electrical impulse, produces a deflagrating or detonating action

Note 1 to entry: The initiator is divided into three categories: 1) igniter, a first element whose output is hot gases and hot particles (igniters may be initiators for solid or liquid *propellant* (3.1.45)); 2) squib, a first element whose output is primarily gas and heat (squibs may be initiators for *gas generators* (3.1.33) and igniters or may be *cartridges* (3.1.6) for actuated devices); 3) detonator, a first element whose output is a high-order *detonation* (3.1.13) (*detonators* (3.1.14) are generally used to effect detonation transfers within explosive trains).

Note 2 to entry: The deflagrating or detonating action is transmitted to the elements following in the train.

Note 3 to entry: Initiators can be electrically (*EEDs* (3.1.16)), optically or mechanically actuated.

3.1.37
laser initiated device
LID
first element (3.1.30) containing *explosives* (3.1.23) that is ignited by laser energy

3.1.38
launcher
launch vehicle
vehicle designed to transport payloads to space

3.1.39
lifetime
period over which any properties are required to be within defined limits

3.1.40
lot
batch
group of *components* (3.1.10) produced in continuous, without uninterrupted production run, with no change in process or drawings

3.1.41
lot acceptance
demonstration by measurement or test that a *lot* (3.1.40) of items meet its requirements

3.1.42
no-fire level
maximal level of input energy with an ignition stimulus (including nominal rise time and shape as required by the system, but with a 5 min extended duration), to a *first element (initiator)* (3.1.36) at which initiation will not occur within a specific reliability and confidence level as determined by test and analysis

Note 1 to entry: The test sequence should be carried out at the hottest temperature of the operating range.

Note 2 to entry: The probability of functioning should be less than or equal to 0,001 at the 95 % confidence level.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

Note 3 to entry: A first element tested at this level shall remain *safe* (3.1.50) and functional and shall guarantee the level of performances required after the no-fire level test.

3.1.43
packaged charge
explosive material in a closed container

3.1.44
primary explosive
reaction extremely sensitive explosive material that will detonate in response to normal environmental stimuli

Note 1 to entry: In their intended role, these materials are sensitive to a range of thermal, mechanical and electrical stimuli, including exposures during processing.

3.1.45
propellant
deflagrating explosive material whose output is essentially gaseous

3.1.46
pyro-mechanism
device intended to perform one or more mechanical actions, using the energy produced by the reaction of an *energetic material* (3.1.19)

3.1.47
pyrotechnics
mixture of fuels and oxidizers that can deflagrate

3.1.48
pyrotechnic device
basic pyrotechnic object (from *explosive train* (3.1.28) or explosive device) containing explosive substances and intended to perform an initiation (e.g., ignition, priming), a pyrotechnic effect transmission, amplification effect, or generation of a function

3.1.49
refurbish
replace *components* (3.1.10) or elements in an explosive device or system to maintain reliability or extend *service life* (3.1.58)

3.1.50
safe
property of an item and its environment that limits its potential for damage to an acceptable risk

3.1.51
safe and arm device
S&A
mechanical or electromechanical device that provides a moveable barrier within the *explosive train* (3.1.28) downstream of the *first element* (3.1.30)

3.1.52
scoop-proof connector
connector shell design in which the male contacts are recessed into the connector body to prevent mismating damage to pins (especially in blind mating applications)

3.1.53
secondary characteristic
any characteristic other than the function

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

3.1.54
secondary explosive
explosive material that is insensitive to heat or handling impact but will detonate under strong shock impulse

3.1.55
semiconductor bridge initiator
SCB
EED (3.1.16) that uses a semiconductor as the bridge element

3.1.56
sensitivity
characteristic of an *explosive* (3.1.23) that expresses its susceptibility to initiation by externally applied energy such as heat, mechanical shock, or other stimuli

3.1.57
sequential firing
application of the firing pulses to *initiators* (3.1.36) separated in time

3.1.58
service life
life that is established by testing or analysis during qualification or acceptance testing and is periodically extended by testing

3.1.59
sneak circuit
undesired function or function that inhibits a desired function

Note 1 to entry: The path may consist of hardware, software, operator actions, or combinations of these elements. Sneak circuits are not the result of hardware failure but are latent conditions, inadvertently designed into the system, coded into the software program, or triggered by human error.

3.1.60
spacecraft
manned or unmanned vehicle purposely delivered by the upper stage of a *launch vehicle* (3.1.38) or transfer vehicle, and designed to orbit or travel in space

Note 1 to entry: A spacecraft is a space segment element.

EXAMPLE Satellite, ballistic probe, re-entry vehicle, space probes and space stations.

3.1.61
space vehicle
manned or unmanned vehicle constructed or assembled for the purpose of manœuvring, moving, operating, or being placed in outer space

Note 1 to entry: A space vehicle can be a *launcher* (3.1.38), a rocket, a payload, a space capsule, a space shuttle, a space plane, a space station, etc., or any assembled combination thereof.

3.1.62
success
simultaneous achievement by all characteristics of required performance

3.1.63
sympathetic firing
firing of other explosive devices due to the output of any other

3.1.64
transfer line
linear explosive assembly in which the explosive material is confined in a metallic sheath plus various layers of over-wrap materials intended to limit radial expulsion of *detonation* (3.1.13) products, but sustain linear propagation of detonation waves

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

3.1.65
through-bulkhead initiator
TBI
relay which provides transition between the *detonation* (3.1.13) from a transmission line inputted, into combustion of the explosive material located output, through a sealed bulkhead metallic *component* (3.1.10)

Note 1 to entry: The bulkhead remains tight after functioning under the specified environment, e.g., pressure and temperature.

3.1.66
ultimate design factor of safety
FOSU
multiplying factor applied to the design load in order to calculate the design ultimate load

3.1.67
yield design factor of safety
FOSY
multiplying factor applied to the design limit load in order to calculate the design yield load

3.1.68
user manual
document provided by the supplier to describe all the appropriate rules of operations

Note 1 to entry: A content description is given in Annex E.

3.2 Abbreviated terms

AIT	assembly integration and tests
AIV	assembly integration and verification
AL	acceptance test load
CDR	critical design review
DC	direct current
DLL	design limit load
DMPL	declared materials and processes list
DRB	delivery review board
DRD	document requirements definition
DSC	differential scanning calorimetric
DTA	differential thermal analysis
DUL	design ultimate load
DYL	design yield load
EMC	electromagnetic compatibility
EMI	electromagnetic interference
FMECA	failure modes, effects and criticality analysis
FRP	fibre reinforced polymer

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

FTA	fault tree analysis
GSE	ground support equipment
ICD	interface control document
KA	acceptance test factor
KQ	qualification test factor
LEO	low earth orbit
MEOP	maximum expected operating pressure
MRR	manufacturing readiness review
MSDS	material safety data sheet
N/A	not applicable
NC	normally closed
NO	normally open
PDR	preliminary design review
QL	qualification test load
RAMS	reliability, availability, maintainability, safety
RF	radio frequency
RFI	radio frequency interference
RFP	request for proposal
S/C	spacecraft
SDS	safety data sheet
SRS	shock response spectrum
TBPC	to be provided by customer
TBPM	to be provided by manufacturer
TBPU	to be provided by user
TGA	thermo-gravimetric analysis
UM	user manual
UNO	United Nations Organization
UNECE	United Nations Economic Commission for Euriope
VTS	vacuum thermal stability

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

3.3 Symbols

@	At
g	standard surface gravity (9,806 65 m/s^2)
h	drop height (m)
He	helium
M	mass of drop weight (kg)
σ	standard deviation

4 Requirements

4.1 General

4.1.1 Background information

Since an explosive item used for flight can function only once, it can never be fully tested before its crucial mission operation. The required confidence can only be established indirectly by testing identical items, within destructive tests on samples from common production lots. Test results and theoretical justification are essential to demonstrate fulfilment of the requirements. The requirement for repeatability shows that product assurance plays a crucial role in support of technical aspects.

The need for statistics requires that the explosive components used in an explosive system be tested and characterized extensively. The variability in components means it is essential that manufacturers provide customers with proof that the delivered items are identical to those qualified.

Failure or unintentional operation of an explosive item can be catastrophic for the whole mission and life-threatening. Specific requirements can exist for the items associated with it. As all explosives, whatever their use, are to be treated similarly, the same requirements, regulations, practices and standards need to be applied to help avoiding human error.

If there is sufficient data to establish the reliability and confidence level for any given performance against any given condition, this should be done. Subsequently, all margins should be converted into standard deviations (*σ*) and be incorporated into the reliability and confidence analysis.

When viewed from the perspective of a specific project context, the requirements defined in this document should be tailored to match the genuine requirements of the particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific project by selection and, in some exceptional cases, modification of existing or addition of new requirements.

The requirements of this document are drawn from the more detailed specifications of AIAA S-113A and ECSS-E-ST-33-11C.

4.1.2 Overview

Being generally applicable, the requirements stated in this clause apply throughout and are not repeated in the clauses relating to specific topics.

As describe in Figure 1, explosive systems and devices use energetic materials in the explosive train (explosives, propellants, powder) initiated by the firing system: mechanical, electrical, thermal, or optical stimuli, for unique (single-shot) functions, e.g. solid booster initiation, structure cutting, stage

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

distancing, pressurized venting, stage neutralization, pyro-valve opening or closing, release of solar arrays, antennas, booms, covers and instruments.

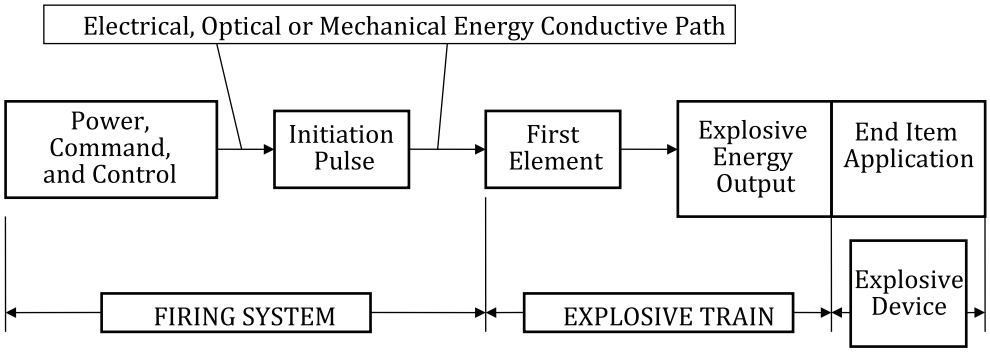

Figure 1 — Explosive system flow diagram

The properties of the initiator govern the major part of the behaviour of the system.

The requirements for initiators and their derivatives, such as cartridges and detonators, are defined in specific requirements related to the specific types.

Properties of explosive components and systems, which cannot be covered by requirements for the initiators alone, are defined in specific requirements relating to the types of explosively actuated device or pyro-mechanisms.

Other components of the explosive system, which can be tested and do not need specific requirements, are subject to the general technical and product assurance requirements. Detailed aspects of these components are included where they have a significant influence on the success of the system.

Single-shot items can never be tested in advance. Particular care shall be taken in their development, qualification, procurement and use, in accordance with the development phases specified in ISO 14300-1.

Safe handling and usage of explosive components are not governed by individual users or the suppliers.

4.1.3 Applicability

This document applies in addition to any existing standards and requirements applicable to spacecraft or launchers considered.

4.1.4 Properties

a) The two states of the properties of the explosive system (before firing and after firing) shall be identified and listed in a specific document for shipper and user.

b) For every explosive component, the function, primary stimulus, unwanted stimuli and secondary characteristics shall be identified and quantified.

c) Only qualified and lot-accepted items shall be used in flight systems.

d) The properties for the two states of the explosive system (before firing and after firing) referred to in item a) of this list shall remain stable over time when subjected to external loads or environmental conditions, within the qualification values.

4.2 Design

4.2.1 General

a) Redundant trains shall be designed such that no component shall adversely affect its substitute.

© ISO 2020 – All rights reserved

AVA Documents Document Sharing Hub
Full document details: BS ISO 26871:2020

b) The system layout should facilitate the replacement of subsystems or components.

c) Parts of the explosive system and devices identified as critical on the basis of a RAMS analysis shall be replaceable.

d) Replaceable parts and substitutes shall be listed in the user manual (content description in Annex E) of the explosive system and devices.

e) The initiation system addressing first elements (initiators) shall be designed such that the minimum stimulus applied to each device in the system is equal to or greater than 2 times the statistical all-fire level, defined on the main parameter of the device, (e.g., current for EED, power density for LID, all fire voltage for EBW, etc.)

f) Tests and/or analyses shall be used to validate that a positive margin exists between the first element minimum output energy and the minimum input energy requirements of the interfacing explosive device. Tests shall also verify that a margin exists between the first element maximum output energy and the upper limit of acceptable input energy of the interfacing explosive device. Explosive charge weight alone cannot be used to predict energy output.

g) Safety system shall be used to guarantee any explosive device unwanted unlocking from other explosive devices in interfaces.

4.2.2 Debris requirements

There is international consensus formalized into ISO 24113 that space activities (including launch vehicle orbital stages, operating spacecraft and satellites) shall manage and minimize debris generation and associated risks.

Explosive devices shall not emit any products that will be detrimental to the integrity, the safety and performance of the vehicle.

In addition, considering that not any long-term orbital debris [orbital velocity higher than 8 km/s in A Zone (LEO: 0 km to 2 000 km); see ISO 24113 for the definition of the LEO protected region] shall remain in space, avionics equipment shall be designed and organized to operate the pyro sequences of orbital stages in a way to avoid debris production during flight and end of mission. Pyrotechnic devices on orbital stages shall be designed so as to comply with the requirements in ISO 24113 regarding the release of space debris into Earth orbit (i.e. no space debris larger than 1 mm in their largest dimension into Earth orbit).

To avoid orbit and ground debris from orbital stages, the architecture, design and dimensioning of explosive train shall take into account:

— mission profile (flight parameters, orbital speed, etc.);

— environment induced;

— characteristics reached by the space system (thermal impact, hazardous on-board remaining materials, etc.);

— stage passivation sequence;

— conditions of the break up process & sequence;

— national authority requirements concerning debris;

— requirements related to ground safety against re-entry;

— impact of debris dispersion on the on-ground footprint;

— …

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

4.2.3 Reliability and confidence levels

a) For the reliability demonstration, the customer shall agree which performance parameters are declared as mean values with associated standard deviation.

NOTE 1 The reliability demonstration is used to justify design margins including the influence of ageing, temperature, and explosive batch.

b) The explosive system shall achieve the specified properties within reliability and confidence level defined at system level.

NOTE 2 All components are contributors.

NOTE 3 This document specifies critical safety and performance properties.

c) The reliability of components shall be equal to or better than 0,999 with a confidence level equal to or better than 95 %.

d) The probability of unwanted functioning of components shall be less than or equal to 0,001 with a confidence level equal to or better than 95 %.

e) The selection of the statistical methods and functional parameters, used to determine the product performances, shall be justified and approved by the customer.

4.2.4 Performance

a) Performances shall be quantified by measurement versus time of initial, transitional, and final values of the specified properties.

NOTE Specified properties are listed in 4.11 and 4.12.

b) The specified time intervals [defined in a)] shall be identified and measured between either

1) a clear reproducible initiation event and the attainment of the performance value, or

2) an initiation event and 90 % of the measured performance value (e.g., initiation event in a closed bomb).

c) The basis of the time shall be specified and justified.

4.2.5 Wanted and unwanted response

a) For wanted response, the response of any component, when subjected to the specified minimum probable stimulus, shall be demonstrated to be more than the specified lower limit agreed between the customer and the supplier.

b) For unwanted response, the response of any component, when subjected to the specified maximum possible disturbance, shall be demonstrated to be less than the specified upper limit agreed between the customer and the supplier.

NOTE This applies to safety and failure.

4.2.6 Dimensioning

4.2.6.1 Strength

The explosive system shall sustain, before, during and after firing:

a) the internal loads due to operation, and

b) the external loads defined by the user.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

NOTE These loads represent the sum of pre-load, static, dynamic, thermal and any other load seen in service.

4.2.6.2 Integrity

a) The explosive system shall maintain its integrity and position during its lifetime.

b) A "margin policy" shall be defined, justified and applied in accordance with the methodology given in Annex A.

c) Components that are intended not to rupture during operation, when installed into their explosive system interfaces, shall be able to withstand the maximum expected operational loads times an FOSU factor.

d) The factors FOSY and FOSU shall be consistent with the values given in Annex B depending on the materials used.

e) The deformation of a component shall not

   1) reduce its specified performance,

   2) affect any part of the system,

   3) cause leakage more than the specified limit,

   4) cause debris more than the specified limit.

4.2.6.3 Explosive charge sizing

a) The methodology for dimensioning the charge of the explosive devices shall be justified and be done by testing or modelling the worst-case conditions.

   NOTE 1 Worst-case conditions include temperature, ageing, radiation effects.

b) A "margin policy factor", K_{MP}; shall be defined, justified and applied in accordance with the methodology given in Annex A.

   NOTE 2 This factor, used to give confidence to the design, covers (non-exhaustive list):

   — the lack of knowledge on the failure modes and associated criteria,

   — the lack of knowledge on the effect of interaction of loadings, and

   — the non-tested zones.

   NOTE 3 Justification can be performed based on relevant historical practice and analytical or experimental means.

   NOTE 4 K_{MP} can have different values according to the explosive materials or device behaviour in the mission profile (e.g. expanding tube, cutter, pyrotechnic actuator).

c) When modelling is performed, K_{MP}, shall include the uncertainties of the model:

   1) defined,

   2) justified,

   3) applied during simulations and analysis.

d) Depending of the development phase, K_{MP} shall include a "project factor", according to the uncertainty in the program level requirement.

   NOTE 5 The project factor applies during the B Phase of the development can become equal to 1 after the PDR with the updated technical specification.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

e) K_{MP} shall include an "explosive factor", for uncertainties on the behaviour of explosive materials in the mission profile and its use configuration.

NOTE 6 The uncertainties can be related to ageing, radiations, temperature influences, batch influence, and chemical compatibility (material, gases, humidity, etc.).

NOTE 7 Use configuration can be, for example, loading density, confinement, thermal exchanges, etc.

4.2.6.4 Motorization

When a mechanical force or torque is complementary to the explosive energy to achieve a motion in an explosive device, the following motorization factor requirements shall apply to dimension the actuation force or torque

a) to provide throughout the operational lifetime and over the full range of travel actuation torques (or forces) according to provision d) or e);

b) to derive the factored worst-case resistive torques (or forces), the components of resistance, considering in-orbit worst-case conditions (environmental effects, e.g. vacuum, temperature, zero G) shall be multiplied by the minimum uncertainty factors specified in Table 1;

Table 1 — Minimum uncertainty factors

Component of resistance	Symbol	Theoretical factor	Measured factor
Inertia	I_T (or I_F)	1,1	1,1
Spring	S	1,2	1,2
Motor magnetic losses	H_M	1,5	1,2
Friction	F_R	3	1,5
Hysteresis	H_Y	3	1,5
Other (harness)	H_A	3	1,5
Adhesion	H_D	3	3

c) The theoretical uncertainty factors in Table 1 may be reduced to the measured factors providing the worst-case measured torque or force-resistive components are determined by measurement according to a test procedure approved by the customer and demonstrate the adequacy of the uncertainty factor with respect to the dispersions of the resistive component functional performances.

d) The minimum actuation torque (T_{min}) shall be derived from the following formula:

$$T_{min} = 2{,}0 \times (1{,}1 I_T + 1{,}2 S + 1{,}5 H_M + 3 F_R + 3 H_Y + 3 H_A + 3 H_D) + 1{,}25 T_D + T_L$$

where

I_T is the inertial torque applied to a device subjected to acceleration in an inertial frame of reference (e.g. spinning spacecraft, payload or other);

T_D is the inertial resistance torque caused by the worst-case acceleration function specified by the customer at the device level;

T_L is the deliverable output torque, when specified by the customer.

e) The minimum actuation force (F_{min}) shall be derived using the following formula:

$$F_{min} = 2{,}0 \times (1{,}1 I_F + 1{,}2 S + 1{,}5 H_M + 3 F_R + 3 H_Y + 3 H_A + 3 H_D) + 1{,}25 F_D + F_L$$

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

where

I_F is the inertial force applied to a device subjected to acceleration in an inertial frame of reference (e.g. spinning spacecraft, payload or other);

F_D F_D is the inertial resistance force caused by the worst-case acceleration function specified by the customer at the device level;

F_L is the deliverable output force, when specified by the customer.

f) The kinetic energy of the moving components shall not be taken into account to meet the specified motorization factor.

4.2.6.5 Sealing

Explosive devices shall be hermetically sealed or contained in an assembly that is hermetically sealed with a maximum allowable leak rate defined in the requirements tables in 4.12 and 4.13. Assemblies that are not hermetically sealed shall ensure the explosives within them are hermetically sealed. Assemblies that are hermetically sealed shall ensure energetic materials installed in them are protected from elements or contaminants in the assembly. Performance and safety of explosive devices shall not be adversely affected by contamination from the environment.

Use of organic materials to enhance seal effectiveness is acceptable provided they are compatible with the explosive materials used.

Seal effectiveness shall be verifiable before and after exposure to thermal and dynamic environments.

All interfaces in the explosive system shall provide adequate protection to preclude intrusion of water, salt, and other contaminants when exposed to worst-case predicted environments. The designer should consider that a launch or space vehicle may remain on the launch pad through very extreme environments and for a prolonged period (to be decided).

4.3 Mission

a) The use of explosive functions, including those for flight termination and range safety, during all phases of the mission, shall be specified.

b) The environmental conditions, life cycle and functions being activated shall be specified.

EXAMPLE Ground storage, transport, launcher ignition, staging and safety functions, payload and spacecraft separation, motor ignition, solar array, antenna, boom or cover release, propulsion system branch opening or closing, de-orbiting.

c) Mission-related requirements placed on the explosive system shall be specified.

4.4 Functionality

a) The firing sequence of each function of the explosive system shall be specified.

b) The explosive system shall react only to a specified stimulus (e.g. nature, range of values) and shall be insensitive to all others.

c) The explosive system shall ensure that the correct stimulus arrives at the specified place at the specified time.

d) The explosive system shall prevent the stimulus from reaching the initiator at any other time.

e) Unwanted functions or malfunctions shall be prevented.

f) The firing sequence (simultaneous or sequential firing) shall cause no anomaly.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

NOTE 1 This applies to secondary characteristics as well as to explosive functions.

g) Explosive systems shall be single-fault tolerant.

h) Explosive systems shall be two-fault tolerant, if premature initiation causes a catastrophic failure.

i) If loss of function is safety-critical or catastrophic, the explosive system shall avoid single-point failures and include at least two initiators.

NOTE 2 Dual bridgewire EEDs are not considered to be redundant within themselves and do not obviate the need for a redundant EED.

j) Provision shall be made within the explosive system to protect its components against unwanted operation or degradation.

4.5 Safety

4.5.1 General

a) The system, including software and procedures, shall be fail safe.

b) For a catastrophic risk, the explosive system shall be fail safe/fail safe or fail operational/fail safe.

c) The response of any explosive device to conditions outside the conditions specified shall be reported by the manufacturer to the user.

d) An explosive subsystem shall only respond to commands intended for that explosive subsystem.

e) Explosive systems and components shall be designed to minimize risk to personnel, equipment, facilities, and environment.

4.5.2 Prevention of unintentional function

4.5.2.1 General

a) The firing pulse (e.g. detonating shock, electrical pulse, light pulse) shall be prevented from reaching any explosive initiator at any time except the correct instant by means of switchable barriers (e.g. electrical, mechanical, plugs, pins).

b) In accordance with the safety “fail safe – fail safe” or “fail operational – fail safe” and the reliability requirements, provision shall be made to prevent firing or degradation in response to radio frequency, direct and indirect effect of lightning, magnetic field and electrostatic discharge. In addition a sneak circuit analysis shall support the safety justification.

c) Explosive system shall demonstrate that not any unwanted sympathetic firing will occur.

d) If the explosive system contains two or more barriers, then at least two of these barriers

   1) shall be independent,

   2) shall not be subject to common cause failure, and

   3) shall each provide disconnection of the firing circuit.

e) For explosive systems involving a potential catastrophic risk, the barrier close to the source of the risk shall be a mechanical barrier.

f) The primary and redundant EEDs shall not be activated through the same electrical firing circuit.

g) Stray circuits or coupling, which can result in unintentional firing, shall be avoided.

© ISO 2020 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020

4.5.2.2 Safe and arm device pre-arm function

a) The pre-arm function shall be the fourth last in a sequence of functions.

b) The pre-arm function shall be independent and respond only to a unique action.

c) The pre-arm function shall remain in its switched state after operation until the fire function has reverted to its initial state.

d) The pre-arm function can include the select function.

NOTE A safe and arm device is not always included.

4.5.2.3 Select function

a) The select function shall be the third last in a sequence of functions.

b) The select function shall select the explosive devices.

c) The select function shall be independent and respond only to a unique command.

d) The select function shall be used to control only one explosive function.

e) The select function shall revert to its initial state after the fire command within an interval agreed with the customer.

4.5.2.4 Arm function

a) The arm function shall be the second-last action in the sequence.

b) The arm function shall be independent and respond only to a unique command.

c) The arm function shall be used to control only one explosive function.

d) It shall be possible to restore its initial (disarmed) state after the arm command within an interval agreed with the customer.

4.5.2.5 Fire function

a) The fire function shall be the last action in the sequence.

b) The fire function may be used to activate a number of explosive devices.

c) The fire function shall be independent and respond only to a unique command.

d) The fire function shall revert to its initial state after the firing command within an interval agreed with the customer.

4.6 Survival and operational conditions

a) The explosive system shall survive during and after the specified sequence of conditions, encountered during transportation, storage, handling and flight, without malfunctioning or degrading performances beyond the specified limits.

b) The explosive system shall operate between the extremes of the ranges and combinations of specified conditions.

c) The limits used for the qualification of elements and interfaces shall comply with the specified reliability and confidence.

d) End users shall specify the characteristics of the expected environment.

© ISO 2020 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 26871:2020