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Space systems — Ground support equipment for use at launch, landing or retrieval sites — General requirements

Systèmes spatiaux — Équipements de soutien au sol utilisés sur les sites de lancement, d'atterrissage ou de récupération — Exigences générales

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 14625 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 14625:1999), which has been technically revised.

Introduction

This International Standard is intended to be used when designing new ground support equipment (GSE) that support space system (launch vehicle or payload) programmes or projects. Existing programmes and projects may utilize this International Standard as far as is practical in accordance with sound management and engineering practices.

The edition of this International Standard applicable at the time the decision is taken to design, construct, manufacture or procure a given GSE remains applicable for the useful life of the hardware. However, if modifications are made to existing hardware, these can be done in accordance with the edition of this International Standard applicable at the time the modification is decided.

When this International Standard is used in procurement, it is advisable that it be reviewed by the programme/project office for applicability, and that only the clauses that apply to the project or programme be included in the procurement documentation.

This International Standard can also be used as a template for the development of specific programme or project GSE specifications or standards.

Space systems — Ground support equipment for use at launch, landing or retrieval sites — General requirements

1 Scope

This International Standard specifies the general characteristics, performance, design, test, safety, reliability, maintainability and quality requirements for ground support equipment (GSE) and systems intended for use at launch, landing or retrieval-site installations, or other locations that are the responsibility of the launch, landing and retrieval site. This International Standard does not specify how to design GSE, but establishes the minimum requirements to provide simple, robust, safe, reliable, maintainable and cost-effective GSE.

This International Standard is applicable to the design of non-flight hardware and software used to support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, service, launch and recovery of space vehicles and payloads at the launch, landing or retrieval sites. As such, the requirements of this International Standard are optional for hardware used only at the manufacturing, development or test sites prior to arrival at the launch, landing or retrieval sites. However, if such GSE is temporarily used at a launch, landing or retrieval site, for whatever reason, conformity with all the safety-related requirements of this International Standard is a minimum requirement for the GSE.

NOTE In the event of conflict between the documents listed in Clause 2 and the contents of this International Standard, the contents of this International Standard supersede except where otherwise noted. The applicable contract or purchase/procurement order takes precedence over the contents of this International Standard in the event of conflicting requirements. No part of this International Standard is deemed or otherwise used to supersede any locally applicable law or regulation, unless a specific exemption has been obtained for this purpose from the appropriate Authority.

2 Normative references

The following referenced documents are indispensable for the application 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 898-7, *Mechanical properties of fasteners — Part 7: Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units*

ISO 1949, *Aircraft — Electrical connectors — Design requirements*

ISO 1966, *Crimped joints for aircraft electrical cables*

ISO 2635, *Aircraft — Conductors for general purpose aircraft electrical cables and aerospace applications — Dimensions and characteristics*

ISO 2964, *Aerospace — Tubing — Outside diameters and thicknesses — Metric dimensions*

ISO 6346, *Freight containers — Coding, identification and marking*

ISO 14620-1, *Space systems — Safety requirements — Part 1: System safety*

ISO 14621 (all parts), *Space systems — Electrical, electronic and electromechanical (EEE) parts*

ISO 14624 (all parts), *Space systems — Safety and compatibility of materials*

ISO 14952 (all parts), *Space systems — Surface cleanliness of fluid systems*

ISO 15389, *Space systems — Flight-to-ground umbilicals*

ISO 15859 (all parts), *Space systems — Fluid characteristics, sampling and test methods*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 22538 (all parts), *Space systems — Oxygen safety*

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60038, *IEC standard voltages*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

IEC 60096 (all parts), *Radio-frequency cables*

IEC 60169 (all parts), *Radio-frequency connectors*

IEC 60189 (all parts), *Low-frequency cables and wires with PVC insulation and PVC sheath*

IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60245 (all parts), *Rubber insulated cables — Rated voltages up to and including 450/750 V*

IEC 60297 (all parts), *Dimensions of mechanical structures of the 482,6 mm (19 in) series*

IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60364 (all parts), *Electrical installations of buildings*

IEC 60794 (all parts), *Optical fibre cables*

IEC 60874 (all parts), *Connectors for optical fibres and cables*

IEC 60884 (all parts), *Plugs and socket-outlets for household and similar purposes*

IEC 60947 (all parts), *Low-voltage switchgear and controlgear*

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

IEC 61086 (all parts), *Coatings for loaded printed wire boards (conformal coatings)*

IEC 62305 (all parts), *Protection against lightning*

IEC 62326 (all parts), *Printed boards*

3 Terms and definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

3.1.1
cognizant authority
organization that is recognized as having expertise in one or more technical disciplines

EXAMPLE ISO, IEC.

3.1.2
commercial-off-the-shelf
COTS
equipment, including hardware and associated software/procedures, that is commercially available from current industry inventory

3.1.3
critical weld
weld whose single failure during any operating condition could result in injury to personnel or damage to property or flight hardware

3.1.4
flight hardware lifting device
structural or mechanical items between the crane hook and the flight vehicle interface that are used to lift the flight hardware

EXAMPLE Sling, cable, shackle, beam.

3.1.5
ground support equipment
GSE
non-flight systems, equipment or devices necessary to support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, servicing, launch and recovery of a space system at launch, landing or retrieval sites

3.1.6
safety critical
any condition, event, operation, process, equipment or system with a potential for personnel injury, fatality or damage to, or loss of, equipment or property

3.1.7
safety factor
ratio of ultimate strength, breaking strength or yield strength to the material design limit stress

3.1.8
safe working load
assigned load, as shown on the identification tag, which is the maximum load the device or equipment is permitted to handle and maintain in operation

3.1.9
sneak circuit
unexpected path or logic flow within a system that, under certain conditions, can initiate an undesired function or inhibit a desired function

NOTE Sneak circuits are not the result of hardware failure, but are latent conditions inadvertently designed into the hardware, or coded into the software, and triggered by timing or human error.

3.2 Symbols and abbreviated terms

A-50	aerozine-50
CFC	chlorofluorocarbon
CIL	critical items list
COTS	commercial off-the-shelf
ECS	environmental control system
EEE	electrical, electronic and electromechanical
EMC	electromagnetic compatibility
EMI	electromagnetic interference
FMECA	failure mode, effects and criticality analysis
GSE	ground support equipment
ICD	interface control document
LH_2	liquid hydrogen
LHe	liquid helium
LN_2	liquid nitrogen
LOX or LO_2	liquid oxygen
MMH	monomethylhydrazine
NDT	non-destructive test
NH_3	ammonia
N_2H_4	hydrazine
N_2O_4	nitrogen tetroxide
OMD	operations and maintenance documentation
PCB	polychlorobiphenyl
PHE	propellant handlers ensemble
PVC	polyvinyl chloride
RF	radio frequency
SCAPE	self-contained atmospheric protective ensemble
SCC	stress corrosion cracking
SI	international system of units
UDMH	unsymmetrical dimethylhydrazine

4 General

The general design requirements and criteria described in this International Standard are the minimum requirements necessary to meet the needs and expectations of internal customers (e.g. safety, reliability, maintainability, quality, supportability) in a cost-effective manner. In order to meet customer expectations, GSE may need requirements that are more stringent than those specified herein. In such cases, requirements that exceed the provisions described in this International Standard shall be determined by the responsible design organization in consultation with its customers (e.g. users, operators).

5 Functional designations

5.1 General

GSE covered by this International Standard shall be classified according to one of the functional designations given in 5.2 to 5.6. Under each functional designation, GSE can be classified by criticality, whereby the GSE

a) either physically or functionally interfaces with flight hardware/software,

b) is classified as safety critical, and/or

c) generates data used in determining flight worthiness/certification.

The GSE is assessed as safety critical if loss of the GSE or improper performance could result in loss of life, loss of flight hardware or damage to flight hardware. The GSE defined herein shall be subject to the configuration control requirements specified in the approved programme configuration management plan.

5.2 Servicing GSE

Servicing GSE is equipment used to supply electrical power or fluids to the flight hardware and/or associated GSE. Typical functions of servicing GSE are those functions of storage, transfer, flushing, purging, pressurizing, conditioning, vapour disposal and decontamination of propellants and other fluids required by the flight hardware up to and including the launch terminal count and/or lift-off.

5.3 Checkout and test GSE

Checkout and test GSE is equipment used in the test and checkout of flight hardware and/or associated GSE. Typical functions of checkout and test GSE are the functions of stimuli monitoring and evaluation.

5.4 Handling and transportation GSE

Handling and transportation GSE is equipment used for the movement and support of flight hardware and/or associated GSE. Typical types of equipment used in the handling and transportation category are slings, dollies, trailers, shipping containers, support stands, jacks, hoists, strongbacks and special handling mechanisms.

5.5 Auxiliary GSE

Auxiliary GSE is equipment used to align, access, protect and calibrate flight hardware. Auxiliary GSE includes, but is not limited to, protective devices, access stands and platforms, and alignment or calibration hardware.

5.6 Umbilical GSE

Umbilical GSE is equipment used to interface directly with flight hardware for transfer of fluids, electrical power or electronic signals to and from the flight vehicle element intended for use up to and including launch terminal count and/or lift-off.

6 Characteristics

6.1 Performance characteristics

6.1.1 Operability

GSE shall support the flight hardware operational requirements and shall be designed to ensure that it does not degrade or contaminate associated flight or ground systems, subsystems or experiments during use, checkout, servicing or handling.

6.1.2 Interfaces

GSE shall meet the requirements of all interfaces with new or existing flight and facility hardware or software. Future system compatibility shall be in accordance with identified interfaces. GSE hardware shall meet the requirements of the applicable interface control document (ICD).

6.1.3 Producibility

GSE hardware shall provide for ease of production, manufacture, construction and inspection. Special care shall be taken to avoid imposing close manufacturing tolerances, unless required by design and performance.

6.2 Physical characteristics

6.2.1 Limited life

Use of items with a life of less than the useful life of the system, or equipment for which the items are intended, shall be avoided whenever possible. Items with limited life shall be identified. Identified limited-life items shall be controlled from the date of manufacture through operational use, including storage. Provisions will be made for replacement or refurbishment of these items after a specified age or operating time/cycle. Status of limited-life cycle items and waivers on limited-life items shall be maintained. Elapsed time or cycle indicators shall be employed to accumulate operational time or cycles if critical.

6.2.2 Useful life

GSE shall be designed for a useful life appropriate to its mission. When a useful life is not identified by programme or mission requirements, a goal of 10 years may be used. During this period, normal preventive maintenance, repair, modification or calibration may be accomplished to maintain specified performance.

6.2.3 Protective coating

Protective coating of hardware shall be appropriate to the condition, use and environment to which the GSE will be exposed during its life cycle. The coating shall minimize corrosion and should indicate its use (see 6.2.4).

6.2.4 Colours

The colours given in Table 1 should be used for the type of GSE indicated.

Table 1 — Colours for GSE

Colour	GSE type
Grey or blue	Consoles and panels
Grey or orange	Structural steel
Red	Remove before flight, safety and protective equipment
White	Transportation containers
Black	Panel lettering
Yellow or white	Handling and transportation equipment

6.2.5 Metric system

New GSE shall use the metric system in accordance with ISO 1000.

6.2.6 Redundancy

Redundant systems, subsystems or components shall be physically separated or otherwise protected to ensure that failure of one will not prevent the other from performing the function.

6.3 Reliability

GSE shall be designed to meet system availability and/or dependability requirements. GSE shall be designed to minimize the probability of system failure and reduce the severity of the failure effect of the system. As a minimum, GSE shall be designed to be fail-safe, except for structure and pressure vessels in the rupture mode. The quality management system of the supplier shall provide appropriate procedures and instructions to perform and document analyses like the failure mode, effects and criticality analysis (FMECA)/critical items List (CIL), reliability diagrams and, in particular cases**,** sneak circuit analysis, or equivalent.

6.4 Maintainability

GSE shall be designed to minimize the complexity and duration of maintenance, the maintenance resources required to keep the system operational and maintenance downtime. High-failure-rate items should be identified for accessibility concerns. Human engineering criteria shall be used regarding accessibility to failed items (see 13.10). Fault detection and isolation should be considered based on criticality and cost of failures.

6.5 Environmental conditions

6.5.1 General

GSE shall be designed to meet natural and induced environments to which it will be subjected during its life cycle. The manager of the geographical location where the GSE is to be located shall provide an environmental document that defines the natural and induced environmental conditions.

6.5.2 Natural environment

GSE used or stored in an exterior environment shall be designed to function properly at its respective geographical location during and after exposure to the natural environment as tailored to reflect programme-defined risk and exposure times.

6.5.3 Launch-induced environment

GSE designed to function during or after exposure to the launch-induced environment shall be designed to withstand the environment defined in programme-induced environmental requirements documents.

6.5.4 Controlled interior environment

Unless otherwise specified by programme requirements documents, GSE designed to function within a controlled interior environment shall be designed to the following temperature and humidity requirements:

a) temperature: +15 °C to +27 °C, with extremes of an uncontrolled temperature of + 10 °C to + 40 °C for a maximum of 1 h;

b) humidity: nominal 55 %, with a range of 40 % to 70 % within the above defined temperature range (15 °C to 27 °C).

6.5.5 Controlled clean environment

GSE used in a controlled clean environment shall be designed to be operated and maintained at a cleanliness level compatible with the intended use.

6.5.6 Uncontrolled interior environment

GSE used in an uncontrolled interior environment shall be designed to survive the most adverse exterior (ambient) environmental conditions for temperature and humidity anticipated at the respective geographical locations during its lifetime.

6.5.7 Fire/explosion hazard environment

GSE operated in locations where fire or explosion hazards may exist, due to flammable gases or vapours, flammable liquids, liquid, gas or solid propellants, etc., shall be hazard-proofed to prevent such hazardous conditions in accordance with the requirements specified in this International Standard.

6.5.8 Environmental test methods

Environmental methods and conditions required for GSE life cycle testing and qualification may be in accordance with accepted national or international aerospace industrial practices, as applicable.

6.5.9 Seismic environment

If GSE may be subjected to a seismic environment, hardware shall be designed to resist the effects of a seismic event using the appropriate criteria and guidelines given in ISO 3010 or in accordance with a national standard.

6.6 Transportability

GSE design shall take into consideration the mobility and transportability constraints imposed by the deployment and maintenance concepts, handling equipment and planned modes of transportation (i.e. road, rail, sea or air). If necessary, GSE shall be capable of being partially dismantled or packed in order to meet the maximum size envelopes of the transportation method to be used (see 12.3). Maximum compatibility with existing procedures, facilities and equipment, including material handling equipment, shall be a design goal.

GSE to be transported by personnel shall be provided with such handling provisions (e.g. handles, hand holds) necessary to meet operational transportability requirements. GSE that exceeds personnel lifting limits shall be provided with material handling provisions (e.g. sling, lift points, castors, skid) necessary to meet the operational requirements for installation/removal, maintenance and use.

7 Documentation

7.1 Drawings and specifications

Drawings and specifications required for the fabrication, construction, installation, modification, test, operation, maintenance or utilization of GSE shall be prepared in accordance with accepted national or international drawing practices, as applicable.

7.2 Technical documentation

Technical documentation (e.g. manuals, reports) shall be prepared in accordance with accepted national or international aerospace industrial practices, as applicable.

7.3 Operations and maintenance documentation (OMD)

Operations and maintenance documentation (i.e. schematics, diagrams, operation and maintenance manuals, lists, etc.) shall be developed to the extent necessary to permit operations and maintenance personnel to fully utilize, operate, troubleshoot and otherwise maintain the GSE within their charge.

8 Supply support

GSE design shall accommodate the supply support system for the identification and acquisition of sufficient spare parts, components, materials and items to support construction, fabrication, installation, activation, tests, verification and operation activities that occur during the life cycle of the equipment or system.

9 Personnel and training

GSE design shall minimize the personnel and training requirements for the operation and maintenance of hardware and software. Hardware and software design shall keep the number and skill levels of personnel to a minimum. OMD shall be utilized as the source documentation in training courses. All GSE shall be designed assuming operations and maintenance will be performed by appropriately trained and skilled personnel, unless otherwise directed.

GSE shall be designed for simplicity of use, redundancy and controls that are self-explanatory. The design shall provide for appropriate safety and warning devices to alert personnel of impending or existing hazards and shall ensure that normal operations/failures will not adversely affect personnel safety or the safety of the system or equipment. The design shall limit the number of controls and the data provided to the absolute minimum possible, so that only those functions needed by an operator are available. The design shall provide ease of operation so that operators do not require specialized training for normal or emergency conditions. Design features shall ensure ease of operation, safety and economy. The resultant design shall optimize compatibility between equipment and human performance, without requiring personnel training. The training necessary for operation and maintenance of GSE should be included in the training systems for the equipment that the GSE supports.

10 Qualification

Critical systems, subsystems and other components that have significant failure impact shall be qualified in accordance with the provisions of the approved programme/project verification plan.

11 Quality assurance

11.1 General

A supplier of GSE shall establish a quality management system that incorporates appropriate design rules and technical quality requirements. The design shall also include special quality-related requirements, such as special processes, special testing and any other necessary special requirements that produce a quality product. Quality requirements will be defined in programme/project quality and technical requirements documents, specifications, contractual requirements and other specified documentation.

11.2 Responsibility for verification

The concept of quality assurance places primary responsibility for quality of delivered products, materials or services on the supplier. The supplier is also responsible for the verification/quality of subcontractor products. However, where assembly of the system or equipment is at a customer facility, responsibility for verification may be split between the customer and the supplier. Accordingly, the supplier's responsibility for inspection shall be clearly stated in the contract documentation and the customer's role, either as a partner or monitor, shall be specified. A typical statement of responsibility is given in the example below.

EXAMPLE "Responsibility for verification: Unless otherwise specified in the contract or order, the supplier is responsible for the performance of all verification requirements specified herein. Except as otherwise specified, the supplier may use its own facilities or any commercial laboratory acceptable to the customer. The customer reserves the right to perform any of the verifications set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements."

11.3 Testing

11.3.1 General

Testing shall be specified by the engineering documentation and will normally be limited to end-item acceptance testing, to verify compliance with the applicable specifications, and the ability of the end item to perform its functions. See ISO/TR 17400 for general testing guidelines.

11.3.2 Load test

A load test shall be performed on hardware whenever there is reason to question its safety for the intended use. The minimum static test load shall be 125 % of the design or working load. Lifting devices and equipment shall be load tested in accordance with accepted national or international aerospace industry practice, as applicable. The static test load for metallic flight hardware lifting devices shall be 200 % of the design or working load. An alternative to the 200 % static load test shall be a 150 % minimum static load test and a 110 % minimum dynamic test of the design or working load. Non-flight metallic hardware lifting devices shall use a minimum static test load of 125 % of the design or working load. Non-metallic natural or synthetic lifting devices shall be load tested to 100 % of the design or working load and the use shall be limited to 50 % of the design or working load.

11.3.3 Non-destructive test (NDT)

All NDTs of base materials shall be performed in accordance with accepted national or international aerospace industry practice, as applicable.

11.3.4 Test reports

Test reports shall be prepared in accordance with accepted national or international aerospace industry practice, as applicable.

11.3.5 Instrumentation calibration

Calibration of measuring instruments shall be established and maintained in accordance with ISO/IEC 17025.

11.4 Quality conformance verification

A verification programme shall be specified in the contract documentation. This programme shall ensure that examinations and tests are performed to verify that all requirements of this International Standard have been achieved. This quality conformance verification programme shall include:

— tests and analyses of the performance and reliability requirements;

— measurement or comparison of specified physical characteristics;

— verification, with specific criteria, of workmanship;

— test and inspection methods for ensuring compliance, including environmental conditions for performance.

12 Packaging

12.1 Preservation and packaging

Hardware shall be preserved and packaged in accordance with accepted national or international aerospace industry practice, as applicable.

12.2 Shipping containers

Shipping containers shall be compatible with on-site transportation, handling and storage methods. For convenient handling and stacking, containers having a gross weight of more than the maximum weight allowed by human engineering shall be provided with integral skids or pallets for shipment. The recommended minimum skid or pallet thickness is 100 mm. Attach points shall be provided where applicable for crane hoists and tie-downs.

12.3 Weight and size

The weight and cubic displacement of packaging and packing shall be held to a minimum consistent with the requirement of the item and the method of transportation. Oversized hardware shall be designed so that the configuration (i.e. item) may be disassembled as required and packaged for shipment.

12.4 Parts protection

There shall be an efficient, reliable and economical system for the protection of all parts during shipping, handling and storage. There shall be standardization of parts protection procedures, methods, materials and devices, such as carts, boxes, containers or transportation vehicles necessary to prevent damage to parts.

12.5 Precision clean parts

Precision clean parts shall be packaged in such a manner as to preserve the cleaning level of the part until used.

12.6 Marking

Containers shall be marked in such a manner as to identify the contents of the container easily without opening it, in accordance with ISO 6346.

12.7 Environmental recording instruments

Shipment of hardware that is sensitive to the induced and/or natural environment shall include instruments which record the environment with respect to time. Proof of adequate packaging shall be demonstrated if the use of a recording instrument is required but is not feasible in a single-item shipment of a small item.

12.8 Transportation and storage

The packaging shall protect the hardware during transportation and storage.

13 Design and construction requirements

13.1 Structural design

13.1.1 Structural steel and other structures

The design of structural steel, aluminium, concrete and other GSE structures (e.g. access platforms, support stands) shall be in accordance with accepted national or international aerospace industrial practices and the requirements of this International Standard.

13.1.2 Safety factor

A minimum safety factor of 2 against yield or permanent deformation and 3 against ultimate failure or collapse shall be used. The safety factor for flight hardware lifting devices shall be 3 against yield or permanent deformation and 5 against ultimate failure or collapse. The safety factor for non-metallic natural or synthetic material devices shall meet or exceed 5 against ultimate failure or collapse.

13.1.3 Critical weld

Critical welds shall be avoided wherever possible. Critical welds shall be identified by the responsible design organization on the design drawings by placing a flag note in the tail of the critical weld symbol.

The required appropriate non-destructive testing for critical welds shall also be identified by the responsible design organization in the general notes on the design drawings.

13.2 Mechanical design

13.2.1 Pneumatics

The design of pneumatic (i.e. gaseous nitrogen, helium, oxygen, hydrogen, breathing air and special oxygen/nitrogen mixtures) servicing systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable. Vacuum systems or compressed air systems shall be designed in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.2 Cryogenics

The design of cryogenic [i.e. liquid hydrogen (LH_2), liquid oxygen (LO_2), liquid helium (LHe) and liquid nitrogen (LN_2)] servicing systems shall be in accordance with ISO 22538 and accepted national or international aerospace industrial practices, as applicable.

13.2.3 Hypergols

The design of the following hypergolic fuel servicing systems and equipment shall be in accordance with the provisions of the national regulations applicable at the launch, landing or retrieval site:

— monomethylhydrazine (MMH);

— nitrogen tetroxide (N_2O_4);

— hydrazine (N_2H_4);

— aerozine-50 (A-50);

— unsymmetrical dimethylhydrazine (UDMH).

13.2.4 Hydrocarbons

The design of hydrocarbon fuel (i.e. JP-4, JP-5, RP-1, etc.) servicing and storage systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.5 Hydraulics

The design of hydraulic servicing systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.6 Environmental control system (ECS) and coolant servicing systems

The design of ECS and coolant servicing systems and equipment used to condition and control the environment within selected space vehicle, spacecraft or experiment compartments shall be in accordance with accepted national or international aerospace industrial practices, as applicable. Environments in which personnel may be exposed shall be maintained in a condition in accordance with the safety objectives of the launch site.

13.2.7 Life support

The design of life support systems and equipment used or worn by personnel involved in toxic material operations, emergency rescue operations and all activities where the possibility of exposure to hazardous atmosphere exists shall be in accordance with accepted national or international aerospace industrial safety practices, as applicable.

13.2.8 Lifting devices

The design of lifting devices (e.g. cranes, crane bridges, hoists) shall be in accordance with national or international standards, as applicable. When lifting flight hardware, a liftability analysis shall be performed to certify the stability of the lift prior to completion of the final design.

13.2.9 Springs

Spring design shall be in accordance with accepted national or international aerospace industrial practices. See the *Handbook of Spring Design*[4] for suggested methods and practices.

13.2.10 Umbilical design

The design of flight-to-ground umbilicals shall be in accordance with ISO 15389.

13.2.11 Torque limits

Threaded fasteners that require a torque shall use the torque limit criteria specified in ISO 898-7, as a minimum. For threaded fasteners of diameters greater than 10 mm, torquing requirements shall be determined by accepted design methods.

13.2.12 Tethers

Equipment used in areas where the dropping of hardware could result in injury to personnel or damage to flight hardware shall be tethered.

13.2.13 Jacks

The design of jacks shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.2.14 Transportation equipment

Transporters and other motorized GSE used for transportation of flight elements shall be designed to system specifications compiled from appropriate sections of industry and military specifications applicable to the characteristics of the desired end item. Transportation equipment shall ensure that loads imparted to flight hardware are equal to or less than 80 % of the design flight loads. The equipment shall remain stable under any maximum combination of applicable design loads. The minimum stand to tilt ratio between stabilizing and instabilizing moments shall be 1,2 for stationary items and 1,3 for slow moving items.

13.2.15 Pressure vessels

All pressure vessels for use in GSE shall be designed, constructed, tested and certified in accordance with accepted national or international aerospace industrial practices, as applicable.

13.3 Electrical/electronic design

13.3.1 Electrical control and monitor equipment

The design of electrical control and monitor systems and equipment shall be in accordance with accepted national or international aerospace electronic industry practices, as applicable.

13.3.2 Pneumatic and hydraulic mechanical components

The electrical design for pneumatic and hydraulic mechanical components shall be in accordance with accepted national or international aerospace fluid component industry practices, as applicable.

13.3.3 Internal wiring

The design of internal wiring used for electrical interconnection of components or parts within electronic GSE shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.3.4 Pyrotechnic systems

The design of pyrotechnic systems and equipment shall be in accordance with the national regulations applicable at the launch, landing, or retrieval site.

13.3.5 Electrical power

The design of electrical power for systems and equipment shall be in accordance with IEC 60364. Standard voltages shall be in accordance with IEC 60038. Adapters or other electrical devices may be required to ensure GSE compatibility between different power systems.

13.3.6 Bonding and grounding

Bonding and grounding shall be provided in accordance with IEC 60364-5-54. Bonding and grounding verification testing shall be determined based on the safety of personnel, systems, equipment and flight requirements for continuity with the ground. For a bonding and grounding test, the normal resistance across the flight to ground interfaces shall be less than 100 mΩ.

13.3.7 Hazard-proofing

Electrically energized equipment that is operated in a hazardous environment shall be hazard-proofed equipment and wiring, or shall be intrinsically safe in accordance with IEC 60079.

13.3.8 Lightning protection

Lightning protection for GSE at the launch pad, hazardous processing facilities and other hazardous areas shall be designed in accordance with IEC 62305.

13.3.9 Software

Software incorporated in the design of GSE shall follow the recommendations of accepted national or international aerospace industrial practices, as applicable.

13.3.10 Firmware

Firmware incorporated in the design of GSE shall meet the requirements of accepted national or international aerospace industrial practices, as applicable.

13.4 Materials, parts and processes

13.4.1 Materials

13.4.1.1 General

Recovered or recycled materials may be used instead of virgin materials, except in those cases where virgin materials are deemed necessary to ensure adequate performance. For establishing properties, national or international industrial standards, as applicable, shall be used for metal. Applications for materials shall be limited to those materials that are adequately described by controlling specifications or standards of a cognizant authority. Any additional qualifying tests and inspections shall be indicated in the engineering documentation. Control documents may be created for proposed materials that lack such documentation.

13.4.1.2 Hydrogen embrittlement

Materials subject to hydrogen embrittlement shall not be used in applications where the material could be exposed to hydrogen. These materials include, but are not limited to, titanium, maraging steels, martensitic stainless steels and precipitation-hardening stainless steels. Low-strength carbon and austenitic stainless steels are preferred construction materials. When hydrogen-generating processes such as inorganic finishing or plating are utilized, the appropriate embrittlement relief procedure shall be used.

13.4.1.3 Stress corrosion

Materials shall be selected from alloys that are resistant to stress corrosion cracking (SCC), unless the GSE is used and stored in a controlled interior environment as specified in this International Standard.

13.4.1.4 Dissimilar metals

Dissimilar metals shall not be used in direct contact with each other for applications where the operational environment may cause corrosion. Separation by use of barrier tape, protective coatings or other methods of isolation shall be used in these applications.

13.4.1.5 Toxic materials or formulations

Toxic materials or formulations shall not be specified in GSE design. Toxic products and formulations shall not be generated by a system or equipment. Typical examples of such toxic materials are mercury in liquid or vapour form, polychlorobiphenyls (PCBs), lead-based paints, chlorofluorocarbons (CFCs) and asbestos. Toxic fluids such as N_2H_4, N_2O_4, MMH, UDMH and ammonia (NH_3) may only be used when specifically required by a flight vehicle system requirement. The use of such toxic fluids shall comply with the applicable safety regulations. A material's hazardous analysis shall be performed to determine if the GSE design involves any materials or by-products that may be considered hazardous.

13.4.1.6 Flammability, odour and off-gassing

13.4.1.6.1 General

Materials used in hardware designed for use in direct contact with the flight vehicle element, or in close proximity, shall be qualified for flammability, odour and off-gassing in accordance with ISO 14624.

13.4.1.6.2 Oxygen service

Only materials that are compatible with oxygen shall be selected for use in liquid or gaseous oxygen and liquid or gaseous air systems, in accordance with ISO 22538.

13.4.1.6.3 Reactive fluid service

Only materials that are compatible with reactive fluids (i.e. hydrogen, hypergols, etc.) shall be used in these systems.

13.4.1.7 Heat and blast protection

Coating materials used for heat and blast protection of hardware shall be compatible with the space system propellants, shall not create debris and shall protect the hardware to which it is applied with a minimum of repair after launch.

13.4.1.8 Potting and moulding compound

Potting and moulding compound for electrical connectors shall be compatible with the space system propellants and shall provide a hermetic seal, isolation and insulation of electrical current, and structural support for the connector.

13.4.1.9 Fungus resistance

Materials susceptible to the growth of fungi shall be avoided. When these materials cannot be avoided, the material shall be treated to resist fungus.

13.4.1.10 Liquid locking compounds

Single component liquid locking compounds that are anaerobic (i.e. they remain liquid when exposed to oxygen) shall not be used without prior project/programme approval.

13.4.2 Parts

13.4.2.1 Use of commercial parts

Commercial off-the-shelf (COTS) equipment, parts, items, software or components shall be used to the maximum extent possible when

a) they satisfy the hardware function,

b) they will not degrade the safety or reliability of the flight or ground system, and

c) they provide a cost savings that will exceed possible cost increases due to unique maintenance or logistics requirements, modifications or an increase in the complexity of the interfacing equipment.

In all cases, exact materials of construction and applicable specifications shall be determined for evaluation of material compatibility requirements. Any additional qualifying tests and inspections shall be indicated in the engineering documentation. Control documents may be created for proposed parts that lack such documentation.

13.4.2.2 Electrical, electronic and electromechanical (EEE) parts

EEE parts shall be selected in accordance with ISO 14621. Only EEE parts commensurate with the criticality of the application and the life cycle of the hardware shall be used. Determination of the EEE grade shall be based on the specific circuit function and its associated criticality.

13.4.2.3 Tubing and fittings

Tube fittings used in high-pressure fluid systems shall be in accordance with accepted national or international aerospace industrial practices, as applicable. Tubing shall be in accordance with ISO 2964.

13.4.2.4 Fluid system components

Fluid system components used in the design of liquid or gas systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed fluid components that lack such documentation. Fluid components shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware or loss of mission is a direct concern, fluid components shall be selected from items of the highest practical quality.

13.4.2.5 Electrical power receptacles and plugs

Electrical power receptacles and plugs for GSE shall conform to IEC 60309 or IEC 60884, as applicable. The wiring of receptacles and plugs should be verified to ensure compatibility with the intended destination of the GSE.

13.4.2.6 Electrical power cable

Alternating current (a.c.) power cable shall conform to IEC 60227 or IEC 60245, as applicable, where the presence of polyvinyl chloride (PVC) or rubber is not detrimental to the intended use of the GSE. Power cables for use in environmental chambers or environmentally hazardous areas shall use appropriate aircraft or vacuum-approved cable types.

13.4.2.7 Electrical cable

Flexible multi-conductor jacketed electrical cable shall be in accordance with accepted national or international aerospace electrical industry practices, as applicable.

13.4.2.8 Instrumentation and communication cable

Instrumentation and communication cable shall be in accordance with IEC 60189, where the presence of PVC or rubber is not detrimental to the intended use of the GSE. Power cables for use in environmental chambers or environmentally hazardous areas shall use appropriate aircraft or vacuum-approved cable types.

13.4.2.9 Fibre-optic cable

Fibre-optic cable shall be in accordance with IEC 60794.

13.4.2.10 Electrical hook-up wire

Electrical hook-up wire shall be in accordance with ISO 2635.

13.4.2.11 Radio-frequency (RF) cables

Radio-frequency cables shall be in accordance with IEC 60096.

13.4.2.12 Connectors

13.4.2.12.1 Multi-conductor connectors

Electrical multi-conductor connectors for electrical control and monitor systems and equipment shall comply with ISO 1949.

13.4.2.12.2 Radio frequency (RF) connectors

RF connectors shall be selected from IEC 60169.

13.4.2.12.3 Fibre-optic connectors

Fibre-optic connectors shall be in accordance with IEC 60874.

13.4.2.12.4 Protective covers or caps

Protective covers or caps shall be specified for all electrical connector plugs and receptacles when they are not connected. Protective covers or caps shall

a) be moisture-proof;

b) protect sealing, surfaces, threads and pins against damage;

c) be resistant to abrasion, chipping or flaking;

d) comply with cleanliness requirements for plugs and receptacles on which they are used;

e) be made of material that is compatible with the connector materials;

f) be connected to the cable with suitable lanyard, chain or hinge;

g) be non-static producing;

h) provide RFI protection, where appropriate.

13.4.2.13 Sensors and transducers

Sensors and transducers used in the design of electrical control and monitor systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed sensors and transducers that lack such documentation. Sensors and transducers shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware or loss of mission is a direct concern, sensors and transducers shall be selected from items of the highest practical quality.

13.4.2.14 Exterior electrical enclosures

Electrical enclosures used in exterior applications shall be designed to protect the electrical/electronic devices, apparatus and wiring contained within the enclosure from the effects of the natural and induced environment and to prevent any potential hazardous conditions.

13.4.2.15 Rack, panels and modular enclosures

Electronic racks, panels and modular enclosures used in interior applications shall be in accordance with IEC 60297.

13.4.2.16 Printed boards

GSE printed boards shall be designed, fabricated and qualified in accordance with IEC 62326.

13.4.2.17 Motors

Motors used in GSE shall be in accordance with IEC 60034. Starters and controllers shall be in accordance with accepted national or international aerospace industrial practices for industrial control devices specified in IEC 60947.

13.4.2.18 Threaded fasteners

Threaded fasteners shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed fasteners that lack such documentation. Fasteners shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware or loss of mission is a direct concern, fasteners shall be selected from items of the highest practicable quality. These critical fasteners shall have lot traceability from the manufacturer to the warehouse storage or shall have acceptance testing (chemical and physical properties, where applicable) of fasteners by lot or be proof-loaded prior to use. Other applications shall give primary consideration to reduced cost and schedule requirements.

13.4.2.19 Fluids

Fluids used in GSE shall conform to ISO 15859.

13.4.3 Processes

13.4.3.1 Welding

Welding shall be in accordance with the accepted national or international aerospace industrial practices, as applicable.

13.4.3.2 Brazing

Brazing of steel, copper, aluminium, nickel and magnesium alloys and induction brazing shall be in accordance with accepted national or international aerospace industrial practices, as applicable to non-flight equipment.

13.4.3.3 Soldering

Soldering shall be in accordance with accepted national or international aerospace industrial practices, as applicable to non-flight equipment.

13.4.3.4 Tube assembly

Fabrication and installation of tube assemblies shall be in accordance with accepted national or international aerospace industrial practices, as applicable to non-flight equipment.

13.4.3.5 Fitting lubrication

Lubrication of tube fittings shall preclude system contamination and shall be compatible with the fluid service.

13.4.3.6 Fluid system cleaning

Cleaning of piping, tubing, fittings, and other fluid system components shall be in accordance with ISO 14952. The cleanliness level and test method shall be specified based upon the application.

13.4.3.7 Riveting

Riveting on systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.4.3.8 Crimping

Crimping shall be in accordance with ISO 1966.

13.4.3.9 Potting and moulding

Potting and moulding of electrical connectors shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.4.3.10 Electrical cable fabrication

Electrical cable fabrication for control and monitor systems and equipment shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.4.3.11 Conformal coating

The application of conformal coating on printed board assemblies shall be in accordance with IEC 61086.

13.4.3.12 Corrosion control

Corrosion control shall be provided for GSE so as to preclude concentration cell, galvanic, intergranular, pitting, stress corrosion and crevice corrosion when subjected to the natural and induced environment anticipated during the life cycle. Appropriate methods for corrosion removal, cleaning, treatment and coating shall be developed to minimize the effects of corrosion.

13.4.3.13 Metal treatment and plating

Metal treatment (including passivation of stainless steel) and plating shall be in accordance with the accepted national or international aerospace industrial practices, as applicable. Cadmium plating is not recommended for use and is prohibited for use in applications that will be exposed to cleanroom, high-oxygen or vacuum environments or where temperatures exceed 232 °C. Cadmium plating may only be used where safety is an overriding factor.

13.4.3.14 Heat treating

All heat treating of steel and aluminium shall be performed in accordance with accepted national or international aerospace industrial practices, as applicable.

13.4.3.15 Electrostatic discharge

All electrostatic discharge (ESD) sensitive components and assemblies shall be handled utilizing accepted national or international electrostatic discharge control practices for the protection of electrical and electronic parts, assemblies and equipment.

13.5 Electromagnetic compatibility (EMC)

Electrical and electronic systems shall be designed to minimize the generation of and susceptibility to electromagnetic interference, in order to eliminate any possible deterioration of performance of the system and surrounding systems. EMC requirements shall be in accordance with IEC 61000, unless more stringent requirements are established by the flight hardware system, such as ISO 14302.

13.6 Identification markings and labels

13.6.1 Systems and equipment

Systems and equipment shall be identified and marked in accordance with accepted national or international aerospace industrial practices, as applicable.

13.6.2 Load test

Hardware that has been load tested satisfactorily shall be identified and marked to show the load test date, safe working load, test load, retest date and quality acceptance.

13.6.3 Piping systems

Ground piping systems shall be identified and colour-coded to indicate the type of fluid contained within and the maximum operating pressure.

13.6.4 Compressed gas cylinders

Compressed gas cylinders shall be identified and colour-coded to indicate the type of fluid contained within in accordance with the national standard of the country of use.

13.6.5 Load capacity

Hardware used for hoisting, transportation, handling and personnel access shall be conspicuously marked to indicate the maximum safe working load.

13.6.6 Test weights

Prior to first usage, all test weights shall be weighed and marked in accordance with the requirements listed below.

a) Manufactured or fabricated test weights provided by a supplier shall be weighed and marked by the supplier prior to acceptance.

b) Test weight marking shall be sufficiently large that the load value is visible to the load test operator at normal working distances up to 6 m. Letters 150 mm high are suggested.

c) Square and rectangular test weights shall have the weight value painted in a contrasting colour on two opposite sides. Markings shall be placed so that they are visible when weights are stacked.

d) Cylindrical test weights shall have the weight value painted in a contrasting colour at two points approximately diametrically opposite.

e) Large field standard weights up to 4 500 kg used as test weights shall be clearly marked in accordance with accepted national or international aerospace industrial practices, as applicable.

f) After initial marking, test weights shall not be re-weighed and re-marked unless the test weights are modified or the physical marking is lost. If the test weights are modified in such a way as to significantly change the weight, they shall not be used until they are re-weighed and re-marked.

g) The weighing and marking of test weights shall be specified on the engineering drawings.

h) In those special cases where there is no practical method of weighing test weights, the calculated weight shall be used and the words “calculated weight” shall be noted for weight identification.

i) Test weight fixtures or weight cages used for single or multiple weight tests shall be marked in accordance with this subclause. The words “fixture weight” shall be noted for weight identification.

13.6.7 Electrical cable assemblies

Electrical cable assemblies shall be identified and labelled at each end of the cable with the assembly part number, cable reference designation number and a cable end marking.

13.6.8 Serial numbers

Serial numbers or other methods of record keeping shall be required on those items, components or assemblies that contain limited-life parts (e.g. valves, regulators) or that require periodic maintenance, servicing or calibration (e.g. pressure transducers, gauges, switches, torque wrench).

13.7 Workmanship

Hardware shall be fabricated and finished such that appearance, fit and adherence to specified dimensions and tolerances are observed, and in a manner that ensures reliable operations in accordance with the requirements specified herein. Particular attention shall be given to the neatness and thoroughness of construction and to the freedom of parts from burrs and sharp edges that might damage associated equipment or cause injury to personnel.

13.8 Interchangeability

Hardware assemblies, components and parts with the same part number shall be physically and functionally interchangeable.

13.9 Safety

Safety requirements shall be in accordance with the launch site safety standards and Government health and safety laws. System safety shall be conducted in accordance with ISO 14620-1. GSE design that involves radiation hazards (i.e. laser, ultraviolet, infrared and microwave emitters; radiological sources; nuclear assemblies) shall be reviewed and approved by the authority in charge of site radiation protection.

13.10 Human performance

13.10.1 General

Human engineering criteria for GSE design shall be in accordance with accepted national or international aerospace industrial practices, as applicable.

13.10.2 Operating characteristics

Noise, light, smoke, fumes, heat and vibration created by equipment shall not exceed the limits defined in human engineering criteria.

13.10.3 Personnel force limits

Human engineering criteria shall be used to determine the maximum weight that one or two personnel can lift, carry or handle. Human engineering criteria shall also be used to determine the maximum force limits to perform any other hand actuation operation. Special consideration shall be given to equipment handling inside or adjacent to flight vehicle elements.

13.10.4 Propellant handlers ensemble (PHE) operators

GSE shall be designed to minimize the requirement for operations and maintenance personnel to wear protective clothing such as a PHE during normal operations and maintenance.

NOTE PHE was previously called “self-contained atmospheric protective ensemble” (SCAPE).

Valves, gauges, levers, bolts, nuts and any other item required to be moved, turned, manipulated or monitored by personnel in a PHE shall be sized to facilitate operation by PHE-suited operators. Such items shall be located to optimize access to the item while the PHE-suited operator is in a standing position. Sufficient clearance shall be provided to preclude brushing against other surfaces. Systems and equipment shall be designed to avoid requirements for PHE-suited operators to reach into tight areas, stoop to avoid low overhead obstructions, mount supplementary ladders or stairs, touch rough surfaces, or sit, kneel or lie on the floors or decks. Suitable provisions to prevent damaging the PHE and to prevent PHE personnel fatigue and discomfort shall be included in the design.

13.11 Security

Security requirements for GSE shall be in accordance with the appropriate programme/project requirements identified for the launch site.

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