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AMENDMENT 1
2005-10-01

Space systems — Flight-to-ground umbilicals

AMENDMENT 1: Prevention of accidental cross-connection

Systèmes spatiaux — Ombilicaux bord-sol

AMENDEMENT 1: Prévention des croisements accidentels de connexions

Reference number
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Foreword

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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.

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Amendment 1 to ISO 15389:2001 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Space systems — Flight-to-ground umbilicals

AMENDMENT 1: Prevention of accidental cross-connection

Page 1

Replace the full stop at the end of the second sentence with the following:

"and also prevention of accidental cross-connection."

Insert the following paragraph at the end of Clause 1:

"Annex A establishes requirements for umbilical connectors and couplings located on the same plate to prevent an accidental service-line cross-connection. There are two groups of requirements: design and symbolic. The design requirements provide the distinctive characteristics of elements for attaching connectors (threaded connections, flanges, etc.). The symbolic requirements provide for the presence of distinctive marking of connectors and couplings (pipelines, cables) by symbols or colour."

Pages 1, 2, and 3

Insert the following terms and definitions alphabetically in Clause 3 and renumber the existing terms appropriately:

3.4
flanged connection
connection at which halves of connectors (3.2) or couplings (3.3) are mated by means of flanges

3.11
nipple
half of a hydraulic or gas coupling with an external sealing surface

3.18
threaded connection
connection at which halves of connectors (3.2) or couplings (3.3) are mated by means of a thread on each of the halves

3.24
union
half of a hydraulic or gas coupling with an internal sealing surface

Page 4

Insert "Umbilical design shall ensure prevention of accidental cross-connection." at the end of the third paragraph of 4.1.

Page 10

Add the following new subclause after 5.3.6:

5.4 Prevention of accidental cross-connection

The design requirements for connectors between lines and the flight plate and between lines and the ground plate preventing accidental cross-connection shall be in accordance with Annex A.

Page 11

Add the following new subclause after 6.4:

6.5 Cross-connection verification test

Correctness of connectors between lines and the flight plate and between lines and the ground plate shall be tested in accordance with Annex A.

Page 11

Add the following Annex A after 6.5:

Annex A
(normative)

Prevention of accidental cross-connection

A.1 General considerations

Due to launch vehicle and spacecraft assembly specific features, arrangement of many connectors and couplings in close proximity to each other is required. During assembly, test, and operation, connectors and couplings should not be in a zone of simultaneous service. All connectors and couplings in this zone shall have a very different design and be marked to prevent an incorrect connection.

The accidental cross-connection of service lines can result in very serious and even tragic consequences. For example:

— supplying other gas or fluids;

— supplying gas or fluid under other pressure;

— supplying the electric power with other parameters;

— supplying an error signal (command).

Therefore, differences in design of connectors and couplings that are located close to each other should be significant. Such differences can be both in design and in marking for identification.

International cooperation in space engineering assumes international cooperation in design, manufacture and operation. The application of uniform methods will increase the reliability of space systems by minimizing the accidental cross-connection of connectors and couplings. The application of unified symbols will promote mutual understanding and personnel training.

This annex applies to umbilical assemblies connected to pipelines and equipment cables at a launch complex or to the launch vehicle or spacecraft. This annex can be used by those participating in the development, renovation, modernization, and operation of launch complexes.

A.2 General requirements

Electrical and fluid couplings located on a single umbilical carrier plate (or carrier) should be designed to prevent the accidental cross-connection of incorrect coupling halves.

This requirement may be implemented in one of the following ways:

a) use of a different design;

b) application of distinctive marking.

The simultaneous use of both methods is recommended.

A.3 Design requirements

A.3.1 Threaded connections

The electrical and fluid connectors and coupling located on one plate should have different threads. Threads should be distinguished by

a) diameter - not less than by 4 mm;

b) arrangement - external, internal;

c) step - not less than by 1,5 mm;

d) number of threads per unit of measure;

e) direction – right-hand or left-hand threads.

Other features include the following:

— guide elements;

— fixing elements;

— arrangement of nipples and unions, etc.

A.3.2 Flanged connections

The electrical and fluid connectors (umbilicals) located on one plate should have different flanges. These flanges should be distinguished by one or more of the following:

a) geometrical configuration (circle, oval, square, triangle, irregular polygon, etc.);

b) flange thickness;

c) attachment (perpendicular or parallel to plate) orientation;

d) quantity of attachment features;

e) arrangement of attachment features;

f) type of fastening elements (bolt with a nut, screw, pin, lock);

g) diameter of threaded elements;

h) quantity of connectors (couplings) located on a flange;

i) location of flanges [flanges on both halves of connectors (couplings) or only on a part of the pipeline (cable)].

The following types of fastening elements are recommended:

— removable bolts or screws;

— folding bolts;

— locks with different attachment methods.

The electrical connectors (except the requirements previously specified) should differ in the following:

— pin quantity;

— geometrical configuration of pin combination;

— pin diameter;

— arrangement of “pin–socket” couple.

A.4 Marking requirements

A.4.1 General requirements

Marking by figures, letters, or symbols and colour is recommended. See A.4.2 to A.4.5.

Both halves of connectors and couplings and also pipelines and cables attached to them shall have identical marking.

Marking shall be put directly on both halves of connectors and couplings and on the pipelines and cables attached to them.

Marking may be by a mechanical method or by painting.

When it is impossible to mark both halves of connectors and couplings or pipelines and the cables directly, one half should have a label marker. In this case, places for label attachment shall be provided on halves of connectors and coupling (pipelines and cables).

On vacuum pipelines, an inscription “vacuum” is made besides marking.

A.4.2 Marking figures and letters

The marking content and location shall be indicated on the schematics, diagrams, and drawings. The size of figures and letters should be not less than 5 mm. The marking shall be clear and precise to preclude an error in reading and understanding.

A.4.3 Marking by symbols

The marking symbols shall indicate danger, which can arise with cable (pipeline) damage (for example, high voltage/pressure and poisonous substances).

The halves of the marking symbols should correspond to the International Standard guidelines or as specified on the schematics, diagrams, and drawings. In all cases, the symbols shall be explained in the operation and maintenance documentation.

The symbol size should be not less than 15 mm.

The symbol colour should be black or white depending on the background. Symbols should be placed inside an equilateral triangle with the size of the side not less than 24 mm. The colour of the triangle background should be yellow.

Symbol tracing should be clear and precise to avoid an error in understanding.

The concrete parameters can be utilized as marking, for example, voltage 25 V.

A.4.4 Marking by colour

Colour marking should indicate the following:

a) the function (application) of a connection (unit A power supply, bottles, charging control, tank fill and drain, tank pressurization, fire suppression, etc);

b) the value of dangerous characteristics (more than 250 V, more than 4 MPa, etc);

c) the fluid and gas type [combustible gases (including liquefied); noncombustible gases; inert gases; air; combustible fluids; water; fire-suppression products; mixes, etc];

d) the particular fluid or gas (oxygen, hydrogen, kerosene, helium, nitrogen, compressed air, etc).

In the case where the use of a colour symbol is required for marking bands (loops), the following will apply:

— symbol size should be not less than 15 mm;

— line thickness should be not less than 5 mm;

— colour should correspond to a function, characteristic, type, etc.;

— width of a band should be not less than 5 mm.

If it is necessary to identify several characteristics, add one or more bands. The first band should be the function, followed by additional bands with a description.

Additional bands corresponding to other characteristics may be added to the basic colour bands.

The distance between additional bands and also from an edge of a basic band is not less than 5 mm.

When using cables with colour isolation, the colour of the isolation shall correspond to a function colour.

When using painted pipes, their colour shall correspond with the function colour.

When applying additional bands, black or white lines that are 1-mm thick should be applied to the edges of colours that are similar (e.g. red/orange) or the same.

Marking colour shall be established to meet national, customer, or launch vehicle supplier requirements. The convention used shall be identified in the appropriate operations manual.

A.5 Verification

A.5.1 General

The verification of proper connection may be accomplished in three stages (phases):

a) verification of the connector and coupling on the part of a vehicle;

b) verification of the connector and coupling on the part of ground support equipment;

c) verification of the umbilical in a connected state.

A.5.2 Electrical connectors

The verification of electrical connectors is performed by applying a signal minimum voltage and frequency, used on the launch vehicle. This is performed during factory and independent tests.

A.5.3 Fluid coupling

The verification of fluid coupling is performed by leak testing with a fluid according to this International Standard at a minimum pressure used on the launch vehicle. This is performed during factory and field tests.

A.5.4 Umbilical

The verification of an umbilical is performed according to A.5.2 and A.5.3 with the plates or their simulators connected. Pressure and voltage are supplied to umbilicals at first sequentially and then to all connectors simultaneously. This verification may be performed during any stage of testing.

A.5.5 Unsatisfactory results

If the results of the verification are unsatisfactory, the defective umbilicals are replaced or repaired and retested.

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Foreword

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Introduction

This International Standard establishes the general requirements and criteria for flight-to-ground umbilical systems used by space systems. The purpose of this International Standard is to establish uniform engineering practices and methods and to ensure the inclusion of essential requirements in the design of reusable flight-to-ground umbilical systems that support the launch of space systems. This International Standard is not intended to define how to design umbilicals but to define the minimum requirements umbilicals must meet.

Space systems — Flight-to-ground umbilicals

1 Scope

This International Standard defines the general criteria for the development of flight-to-ground umbilical systems used by a space system. The criteria specified herein is limited to the service arms or equivalent mechanisms, umbilical carriers and plates, couplings, connectors, withdrawal and retract devices, handling mechanisms and control systems for mechanisms.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 14625, *Space systems — Ground support equipment for use at launch, landing, or retrieval sites — General requirements.*

IEC 60364-5-54, *Electrical installations of buildings — Part 5: Selection and erection of electrical equipment — Chapter 54: Earthing arrangements and protective conductors.*

3 Terms and definitions

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

3.1
carrier
device that groups coupling and connector halves together to provide a common means for their positioning, retention, unlocking, and separation

NOTE The term is commonly used in relation to the facility ground-side of umbilical interfaces.

3.2
connector
device, consisting of two halves, that permits engagement and disengagement of electrical circuits at an interface

3.3
coupling
device, consisting of two halves, that permits transfer of fluid across and disconnection at an interface

3.4
ground control
equipment, fluids, or signals, provided for command or control purposes, which are neither on board nor originate on board the launch vehicle

3.5
handling mechanism
device used to provide positioning, manipulation, and physical dead-weight support of an object

3.6
inflight
term that denotes an occurrence or function after vehicle lift-off

3.7
interface
region of mating or boundary between separating or cooperating elements established by a governing characteristic

EXAMPLES Ground-to-vehicle interface, physical interface, or responsibility interface.

3.8
launch processing system
operating consoles, data handling and display equipment, and the associated transmission system configured to issue commands and analyse and display response data required in checkout and operation of ground support equipment (GSE) and flight hardware

3.9
lift-off
term designating the instant of flight at which the vehicle's contact is terminated with all areas of hold-down and/or support devices

NOTE Lift-off is commonly called "first motion" of the vehicle.

3.10
plate
device that groups coupling and connector halves together to provide a common means for retention

NOTE 1 The plate is a passive device, containing cooperating but usually immobile portions of positioning, locking, and separation machinery.

NOTE 2 The term is commonly used in relation to the vehicle side of umbilical interfaces or with the carrier.

EXAMPLE Carrier plate.

3.11
preflight
term that denotes an occurrence or function before vehicle lift-off

3.12
rise-off
term applied to a device to denote that its actuation is solely caused by a vehicle's vertical motion

3.13
service arm
retractable structure, usually attached to a tower used to provide either umbilical requirements, personnel access, or both to the flight vehicle

NOTE 1 A service arm is commonly called access arm, umbilical arm, or swing arm, depending upon whether it provides services for access only, umbilicals only, or both, respectively.

NOTE 2 The service-arm retracting motion may be along an arc or in a vertical or horizontal plane.

3.14
T–0
time minus zero
last moment in the launch countdown, measured in seconds, at which time the launch vehicle lifts off the ground

3.15
tail service mast
retractable structure used to provide umbilical requirements to the aft portion (tail) of a space vehicle

NOTE Movement is usually a rotation about a pivot point away from the vehicle.

3.16
umbilical
device that provides fluid (supply/return and purge) and electrical requirements at physical interfaces between ground facilities and various areas of a space vehicle

3.17
umbilical assembly
mated carrier and plate containing all couplings and connectors for a specified umbilical region of the vehicle

3.18
umbilical service line
any fluid line or electrical cable routed through an umbilical such as a service arm or equivalent mechanism that is to be disconnected prior to engine ignition or at T–0 or in flight

3.19
umbilical supply device
movable structure used to connect and/or disconnect the umbilical plates at various locations on a space vehicle

3.20
umbilical system
functional assembly of all items required for providing fluid and electrical servicing to a launch vehicle and/or a payload

NOTE 1 This system usually includes the following:

— service arms or equivalent umbilical supply device mechanisms;

— umbilical carriers and plates;

— couplings and connectors, all separation, withdrawal, and retraction devices;

— control equipment;

— control fluids and electrical signals;

— all interconnecting lines across the service arms or the equivalent mechanism on the ground side.

NOTE 2 The mating-half interface for the couplings/connectors and umbilical carrier should be located on the exterior surface of the launch vehicle at an orientation compatible with the launch structure.

4 General requirements

4.1 Umbilical system principles

The umbilical design shall not require reconnection of disconnected umbilical service lines to abort safely on the launch pad. Passive umbilical systems disconnected at a launch vehicle's first motion during launch by gravity is the preferred system over active systems to minimize failure modes and potential damage to the flight hardware.

Adequate safety margins and/or system redundancy shall be included in the design to preclude premature umbilical disconnect that can jeopardize the flight hardware environment or vehicle and/or personnel safety. System design shall be a balance between ensuring umbilicals remain engaged and sealed under all static and dynamic pre-launch environments and safely disconnecting at lift-off.

Disconnect after lift-off should have at least secondary and, if possible, tertiary modes to ensure vehicle safety as the primary feature and protection of the ground systems under the launch environment as a secondary feature. Umbilical failures shall not propagate into the flight vehicle system. Flight-to-ground umbilical systems shall conform to the general requirements specified in ISO 14625.

4.2 Mating

4.2.1 Time

The time required to connect and verify an umbilical assembly shall be minimized. Factors that should be considered include:

a) the number of steps required;

b) the number of component parts to be installed or manipulated in the connection process;

c) availability of, and accessibility with, mechanical handling aids;

d) available working space;

e) requirements for operating personnel;

f) safety requirements;

g) alignment requirements;

h) the adaptability to automated verification.

The goal for the time required to perform the mating operation is one work shift or less.

4.2.2 Handling and engagement

Rapid handling and engagement are necessary in order to minimize impact on the ground turnaround and crew size for launch support. To provide ease with which an umbilical assembly is mated and connected to a vehicle, consideration shall be given to mass, torque requirements, manual force required for connection, and rigidity of electrical cables, flex lines, propellant flex lines, ducts for environmental control systems, etc.

4.2.3 Alignment

The umbilical assembly shall be self-aligning. The design shall not require critical manual horizontal, vertical, or parallel alignment for mating.

4.2.4 Verification

Mated umbilical assemblies shall allow quick and reliable verification of integrity.

4.2.5 Materials

Umbilical materials shall be compatible with service line media, shall be corrosion-resistant, and shall meet flammability, odour, and off-gassing, or vacuum-stability requirements that may be required by the flight hardware system.

4.3 Mass

Umbilical parts shall be as lightweight as feasible to minimize launch-induced loads and ground-handling requirements.

4.4 Loads

4.4.1 General

Umbilical design shall accommodate all static and dynamic pre-launch loads, such as dead loads, fluid pressure loads, and catenary loads imposed on all lines running from the flight vehicle to the supporting structure coupled with wind loads. Connections shall be located on or within the carrier so as to evenly distribute the forces required for disconnect or retain the vehicle about the locking, release, and ejection mechanisms. The same consideration shall also be given to the design of the handling systems. Loads during lift-off (such as retractable, acoustical, vibrational, and heat- or blast-pressure loads, as applicable) shall also be accounted for during umbilical development.

4.4.2 Side loads

Carriers and plates shall be designed and used in a manner that prevents connectors or couplings and latching and/or carrier mechanisms from having side loads.

4.4.3 Tracking loads

The vehicle shall bear all loads associated with the tracking of vehicle motion by the umbilical assembly and the attached hardware and the loads shall be as low as possible, consistent with practical GSE design and reasonable vehicle interface structural requirements. Other than vehicle requirements, determining factors for loads shall include overall costs for the life of the program.

4.5 Contamination prevention

Both halves of all fluid couplings shall incorporate internal devices for the protection of the system from debris during the launch, flight, and recovery operations. The devices shall be normally in the closed position and shall be opened automatically by the engagement of the two coupling halves. The device shall close automatically as the two coupling halves are separated. The device may also be capable of being opened or closed upon command from the ground control system or launch processing system.

4.6 Purges

Electrical umbilical connectors shall be provided with an inert environment, to the extent required to ensure safety. Cryogenic connections should be purged as required to prevent moisture condensation as well as resulting ice build-up or liquefaction of air. Systems for hypergolic or other corrosive or hazardous fluids shall have a purge, scrubbers, etc., as required for safe connect and disconnect operations. There shall be only one purge in a cavity between the carrier and the plate.

4.7 Leak detection

When hazardous fluids are present, such as hypergols or nitrogen, umbilical couplings shall utilize primary and secondary seals and shall have sensors to detect primary and secondary seal leakage to the extent possible. Redundant seals and integrity monitoring are desirable to achieve this goal in most instances.

4.8 Leakage disposal

Disposal of hazardous media leakage from couplings shall be provided during vehicle servicing.

4.9 Fluid couplings

The design of couplings for liquid or gas service lines to the umbilical shall ensure that it is impossible to mate a coupling improperly.

4.10 Electrical connectors

Electrical connectors shall be dead-faced and self-aligning. Data bus, power, and command functions shall be in separate connectors to the extent possible. Connectors contained in the carrier shall not be self-locking. The design of electrical connectors shall prevent incorrect mating of the connector.

4.11 Grounding

Umbilicals shall be grounded in accordance with the requirements of IEC 60364-5-54.

4.12 Electromagnetic compatibility (EMC)

Umbilical 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 the performance of the system and surrounding systems. EMC requirements shall be in accordance with the requirements established by the flight hardware system.

4.13 Lightning current paths

Umbilical connections above the base area of a space vehicle shall be eliminated or minimized to reduce the number of electrical paths through the vehicle from a lightning strike on the facility structure.

4.14 Environmental conditions

4.14.1 General

A flight-to-ground umbilical shall meet natural and induced environments to which it is to be subjected during its life cycle. The natural and induced environmental conditions shall be defined and taken into consideration during the umbilical development.

4.14.2 Natural environment

Flight-to-ground umbilicals shall function properly at their respective geographical locations after exposure to the natural environment and shall be tailored to reflect program-defined risks and exposure times.

4.14.3 Launch-induced environment

Flight-to-ground umbilicals shall function properly when subjected to the launch-induced environment such as launch-induced acoustics, vibration, plume impingement, heat, and blast pressures, as applicable.

4.14.4 Fire- and/or explosion-hazard environment

Umbilicals operated in locations where fire or explosion hazards may exist due to flammable gases, vapours, and/or flammable liquids shall be hazard-proofed to prevent such hazardous conditions.

4.15 Component selection

Components used in the design of umbilical systems for a space vehicle shall be qualification tested for the intended application.

4.16 Corrosion control

The natural atmosphere and the induced environment contain residue that is readily deposited on exposed surfaces. This, combined with substantial moisture and generally high temperatures, results in an environment conducive to extensive corrosion of metals. The designer shall provide for corrosion control due to these environmental conditions by selecting materials and coatings and designing equipment for the prevention of crevice, stress, and galvanic corrosion.

4.17 Maintainability

Flight-to-ground umbilicals shall minimize the complexity and frequency of maintenance, the maintenance resources required to keep the system operational, and maintenance downtime. High-failure-rate items should be identified for accessibility concerns. Fault detection and isolation should be considered based on criticality and cost of failures.

4.18 Accessibility

The umbilical shall provide ready access for operating, testing, fault detecting, repairing, and replacing components. The design shall allow these functions to be performed without interfering with other components or assemblies.

4.19 Component position feedback

All remotely operated components used for an umbilical's ground controls shall have position feedback signalling to the extent possible. Command and feedback signals shall not usually be combined in the same connector or cable, regardless of source.

4.20 Connection inspection

The umbilical system shall provide for inspection of the proper mating of all connections between the flight and ground portions of the umbilical.

5 Design guidelines

5.1 Preflight disconnect

It is recommended that the design of the umbilical system has all preflight disconnects. Inflight disconnects are not recommended. In some situations, inflight disconnects are unavoidable. Acceptable alternatives are described in subclause 5.2.

5.2 Inflight umbilical assembly

5.2.1 Inflight preferences

When the vehicle requirement cannot be met by a preflight umbilical assembly only, the preferred design alternative for all inflight disconnects is the rise-off type. The second alternative is to have only those services that are to remain connected to achieve a safe abort routed through the rise-off umbilical assembly. The third preference should be to use a transverse disconnected umbilical activated at T–0, such as a tail service mast.

5.2.2 Rise-off umbilical assembly

5.2.2.1 General

The rise-off umbilical is characterized by the inflight umbilical plate being disconnected as a direct result of a vehicle's vertical motion. The ground carrier remains at a fixed elevation after mating and tracks the vehicle's

motion during pre-launch and launch conditions. The ground carrier may be removed by a device that provides for the unrestrained lift-off of the launch vehicle and protection from plume impingement.

The vehicle plate is subjected to relative motion with respect to the launcher due to the various induced forces (wind, temperature changes, fuel-loading operations, firing effects from the engine, etc.) between the time of umbilical mating and launch. The ground carrier shall be capable of tracking the vehicle to allow for these motions after mating without inducing premature disconnect. The couplings and connectors shall be designed to allow for these motions relative to the carrier plate and ground system.

The ground carrier shall use an alignment device to engage with mating receptacles such as an alignment pin. The device shall ensure the ground carrier is aligned with the vehicle's plate before any of the couplings and connectors start to engage. The carrier shall be elevated for connections by self-locking mechanisms, such as worm screw actuators. Provisions shall be made to limit loads transferred to the vehicle by such systems. Each of the couplings and connectors shall be self-aligning to ensure proper final engagement. Horizontal movement shall be inhibited by appropriate devices.

Disconnection lanyards or mechanisms should include redundant backup in case of failure of the primary mode.

5.2.2.2 Umbilical couplings and connectors

Umbilical couplings and connectors shall be of the nonlatching type. For the fluid couplings, partial motion of the vehicle shall be accommodated by a sliding seal between the coupling halves or by flexible elements of the system (e.g. hose or cable). The electrical connector halves on the ground carrier shall accommodate the vehicle's vertical motion and lateral motion, if applicable. This design shall overcome the dynamic loading due to noise and vibration generated by the engine.

5.2.2.3 Cryogenic coupling

The preferred cryogenic coupling can be of the slip type with dual self-forming lip seals. A tertiary seal may be used to contain a gaseous purge adjacent to the dual seals. The gaseous purge would prevent cryo-pumping and ice build-up on the sliding seal surface.

The cryogenic coupling shall not require the application of additional insulation after mating. The volume between the dual lip seals of the cryogenic coupling should preferably be vented through a tubing connection on the ground carrier side. This vent tubing shall then be monitored for leaks during verification of the connection phase when the coupling is pressure tested with gaseous helium. The couplings shall also provide for the mounting of leak detection devices.

The mounting provisions for the ground-carrier-half of the coupling and the attached flexible duct shall allow lateral and angular motion with respect to the ground carrier to ensure the coupling halves align during engagement and disengagement. The vehicle-half of the coupling shall be rigidly attached to the vehicle plate.

5.2.2.4 Electrical connectors

Data bus, low frequency, command signals, and ground power circuits shall not be in the same electrical connector to the extent possible. The electrical connectors for data bus signals greater than 500 kHz, command circuit connectors, low frequency signal connectors, and ground power connectors shall be grouped within the umbilical and separated from each other to the maximum extent practical. Connectors shall be spaced so physical attachment can be easily accomplished without interference from adjacent connectors. All connectors shall incorporate provisions for carrier-mounting alignment and gaseous-nitrogen purge.

The connector design shall incorporate the necessary devices to ensure proper connection while accommodating vertical relative motion. The connectors should preferably be of the dead-face type.

The faceplate may be purged with gaseous nitrogen. The back-shell shall be sealed or may be purged with gaseous nitrogen. Strain relief devices shall be incorporated in the back-shell design of all connectors to prevent stress-loading of wire terminations.

5.2.2.5 Protective blast cover (ground)

In those cases where the ground umbilical carrier assembly cannot be moved far enough away from the effects of exhaust impingement, a protective blast cover may be required to minimize blast damage. The cover shall be actuated after the vehicle has risen to an altitude that provides sufficient clearance for movement. The outer surface shall have structural and thermal integrity to withstand the direct impingement of the engine exhaust during the launch. The device shall close completely before the vehicle rises to an altitude that allows for direct exhaust impingement on the umbilical couplings. A breakaway lanyard attached to the vehicle is the preferred source of energy for actuating the door.

5.2.3 Tail service mast

5.2.3.1 General

The tail service mast is characterized by the release of the couplings. All couplings and connectors shall be contained in a single or a few assemblies. This umbilical assembly shall enclose the electrical connectors sufficiently to maintain an inert gas purge. Purging of cryogenic couplings shall be used to provide hazard-proofing and the prevention of ice build-up.

5.2.3.2 Umbilical couplings

Because there is no appreciable relative motion between the ground carrier and the vehicle plate, the choice of couplings is not restricted. However, ball-and-cone couplings (with the ball-half located in the ground carrier and the cone-half located in the vehicle plate) should preferably be used. These couplings shall use springs for low pressure, bellows for medium pressure, and pressure-balanced slip couplings for pressures over 3 500 kPa gauge. It is preferable to use dual seals. The volume between the seals is to be vented through the ground side to provide for leakage verification. The coupling shall have provisions for mounting leak detection devices.

5.2.3.3 Electrical connectors

Electrical connectors shall comply with the requirements specified in 5.2.2.4.

5.2.3.4 Locking devices

The vehicle plate and ground carrier shall be secured by a locking device, such as a breakaway bolt. Individual locking devices shall not be incorporated into the design of couplings or connectors. Alignment devices, such as a guide pin, shall be used to align the vehicle plate and ground carrier. These alignment devices shall engage before the locking device or couplings and shall be removed after mating. Side loads and/or motion shall be transferred through a nonbinding-type connection to the vehicle plate.

5.2.3.5 Handling and control systems

For launch vehicle erection, provisions shall be incorporated for the necessary mechanisms and controls to retract the mast. Provisions shall also be made for local manual control of the mechanisms to allow rapid engagement of the ground carrier to the vehicle plate. The retraction of the mast shall also provide protection of the ground system from the exhaust blast of the vehicle's engine.

5.3 Preflight umbilical assembly

5.3.1 General

As in the inflight umbilical assembly, all couplings and connectors shall be contained in as few umbilical assemblies as possible. The vehicle plate and ground carrier shall be secured by a single locking device. Individual locking devices shall not be incorporated into the design of couplings and connectors. Guide pins may be used to align the vertical plate and the ground carrier. These guide pins shall engage before the locking device or couplings. Separation of the ground carrier shall be accomplished by release of the locking device (a mechanical backup shall

be provided). The umbilical assembly shall enclose the electrical connectors sufficiently to maintain an inert gas purge. Purging of cryogenic couplings shall be used to provide hazard-proofing and the prevention of ice build-up.

5.3.2 Umbilical couplings

Dual seals shall be used. The volume between the seals shall be vented through the ground side to provide for leakage verification to the extent required. The couplings shall have provisions for mounting a leak detection device.

It is preferable to use balanced-pressure design features to minimize thrust loads for fluid couplings which convey media at high pressure (3 500 kPa gauge and over). For low pressure (1 000 kPa gauge or less) couplings, it is preferable to use springs for the sealing force, whereas bellows should preferably be used for the sealing force of medium pressure (1 000 kPa to 3 500 kPa gauge) couplings.

5.3.3 Electrical connectors

Provisions for carrier-mounting alignment and gaseous nitrogen purge shall be incorporated into the design of the data bus electrical connection and the command connection. The connectors should be, preferably, of the dead-face type. The back-shell and faceplate may be purged with gaseous nitrogen. To prevent stress-loading of wire terminations, back-shell design of all connectors shall use strain-relief devices.

5.3.4 Locking devices

The locking device may be a collet, ball lock, or other mechanical design and shall have the capability to engage the ground carrier to the vehicle plate at a distance far enough away to allow alignment before the halves of the couplings and connectors mate. A manually operated system shall translate the locking device and any alignment device to maintain the ground carrier in alignment with the vehicle plate while the assembly and all couplings and connectors are engaged simultaneously. Positive locking shall be verified visually.

5.3.5 Handling system

If required, a counterbalanced system shall provide support of the dead weight of the ground carrier, cables, and hoses during manual engagement of the alignment and locking devices. The counterbalance system shall also provide powered forces to withdraw the ground carrier away from the vehicle after release and carrier ejection.

5.3.6 Control system

The ground control system shall use redundant valving, a power supply, and a fluid-stored energy supply. Design of the system shall be for the normal operation in the following sequence:

a) unlocking of the locking device,

b) ejection of the ground carrier and separation from the vehicle plate,

c) withdrawal of the ground carrier and service lines to permit a clearance envelope between the vehicle and the carrier, and

d) subsequent retraction.

The redundancy shall provide for a backup mode to accomplish the normal sequence. Should normal carrier unlock or ejection fail, a secondary device shall accomplish the unlock or ejection in a normal sequence.

The ground control system shall incorporate both local manual control and remote control and monitoring for operation in the final pre-launch sequence. One and only one of them should be enabled and be active at any given time. The system shall be able to provide data inputs to the launch processing system.

6 Test and evaluation

6.1 General

Umbilical systems should be tested in the test facility. Testing should simulate the conditions to which the umbilical system can be subjected during use with the exception of the launch blast, launch acoustic environment, corrosive launch atmosphere, etc. The testing should include, but is not limited to, the following three tests.

6.2 Static test

Static tests include verifying fit and form of the umbilical system with other mating systems. Static tests also ensure mating of the umbilical system in the manner intended and, where appropriate, prove adequate safety margins exist to preclude premature umbilical disconnect.

6.3 Dynamic test

Dynamic testing shall subject the umbilical system to dynamic conditions by tracking the umbilical through all of its excursions that can be encountered while the umbilical is mated to the vehicle. This testing shall also include provisions to ensure loads no greater than allowed are transmitted to the vehicle. Dynamic testing shall also include disconnect if it is a T–0 or rise-off umbilical design.

6.4 Cryogenic test

Cryogenic testing shall subject the umbilical system to the flow of cryogenic liquids that are the same as the actual liquid or a liquid that simulates the actual liquid (liquid nitrogen to simulate liquid oxygen and liquid hydrogen for liquid hydrogen testing in the test facility). Cryogenic testing shall ensure that the umbilical system can transmit cryogenics in a safe manner as intended in the design and that the environmental effects of cryogenic fluids do not inhibit proper operation of the umbilical disconnect system.

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