International Standard

ISO 14953

Second edition
2024-03

Space systems — Structural design — Determination of loading levels for static qualification testing of launch vehicles

Systèmes spatiaux — Conception des structures — Détermination des niveaux de chargement pour un essai statique de qualification des véhicules lanceurs

Reference number
ISO 14953:2024(en)

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

Published in Switzerland

Contents

Page

Foreword

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

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

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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

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

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

This second edition cancels and replaces the first edition (ISO 14953:2000), which has been technically revised.

The main changes are as follows:

— the formula for J_C has been changed so that all the terms are multiplicative,

— a new correction factor has been introduced to take into account the structure imperfections.

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

Space systems — Structural design — Determination of loading levels for static qualification testing of launch vehicles

1 Scope

This document specifies a procedure for determining the loading level of a qualification test of a launch vehicle structure and takes into account all the minimum allowable strength characteristics necessary for these structures.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

3.1
external loading
system of forces, moments and pressures external to a structure and applied to that structure

3.2
failure mode
manner in which failure occurs

Note 1 to entry: A failure mode may be defined by the function lost or other state transition that occurred.

Note 2 to entry: Structural failure modes include: rupture, collapse, detrimental deformation, excessive wear or any other phenomenon resulting in an inability to sustain loads, pressures and corresponding environments, or that jeopardizes mission success.

[SOURCE: IEC 60050-192:2015, 192-03-17, modified — Note 2 to entry has been added reflecting the definition in ISO 10786:2011, 3.19.]

3.3
limit load
design limit load
maximum load, or combination of loads, which a structure or a component in a structural assembly is expected to experience during its service life, in association with the applicable operating environments

Note 1 to entry: Load is a generic term for thermal load, pressure, external mechanical load (force, moment, or enforced displacement) or internal mechanical load (residual stress, pretension, or inertial load).

Note 2 to entry: The corresponding stress or strain is called limit stress or limit strain.

[SOURCE: ISO 24638:2021, 3.13, modified — "maximum expected load" has been replaced by "maximum load".]

3.4
qualification test
required formal contractual test conducted to demonstrate that the design, manufacturing, and assembly have resulted in hardware conforming to specification requirements

Note 1 to entry: Qualification tests are conducted on a flight-quality article at load levels and durations sufficient to demonstrate that all design requirements have been met under the specified environmental conditions. Both protoflight and prototype tests are considered qualification tests.

Note 2 to entry: The qualification test may also validate the planned acceptance programme including test techniques, procedures, equipment, instrumentation, and software.

[SOURCE: ISO 10795:2019, 3.187, modified — The word "used" has been replaced by "conducted"; "hardware designs" has been changed to "hardware"; note 1 to entry and note 2 to entry have been added.]

3.5
safety factor
J
coefficient by which limit loads are multiplied in order to account for the statistical variations of loads and structure resistance, and inaccuracies in the knowledge of their statistical distributions

Note 1 to entry: The two main safety factors are the yield safety factor (for metals) and the ultimate safety factor. They are used to define respectively the yield load and the ultimate load.

[SOURCE: ISO 16454:2007, 3.10, modified — The term has been changed from "design safety factor" to "safety factor"; the symbol "*J*" and note 1 to entry have been added.]

4 Design of loading levels

4.1 General

Qualification tests shall be conducted on a flight-type structure. Because such structures are unlikely to include minimum values for all allowable characteristics, the loads used for design shall be corrected before use in qualification tests. All areas of the launch-vehicle flight structure shown to be critical in probable failure modes shall be considered for the following correction which shall be used to determine the qualification test loading.

4.2 Calculation of qualification test loading

The corrected external loading, P_Q, (force, moment, pressure) used for qualification tests shall be calculated from the following formula:

$$P_Q = P_{lim} \times J_C$$

where

P_{lim} is the limit load used for design;

J_C is the corrected safety factor.

4.3 Corrected safety factor

The corrected factor, J_C, is given by the following formula:

$$J_C = J \times K_{min} \times K_{adj} \times K_T \times K_\theta \times K_\sigma \times K_{imp}$$

where

J	is the safety factor used for design (either for yield or for ultimate conditions);
K_{min}	is the correction factor for thickness (see 4.4.1);
K_{adj}	is the correction factor for adjacent structures (see 4.4.2);
K_T	is the correction factor for thermal gradients (see 4.4.3);
K_θ	is the correction factor for temperature (see 4.4.4);
K_σ	is the correction factor for dispersions (see 4.4.5);
K_{imp}	is the correction factor for geometric imperfections (see 4.4.6).

4.4 Correction factors

4.4.1 Correction factor for thickness, K_{min}

This factor takes into account the influence of the minimum thickness on the structure strength; it is defined as the ratio of the thickness of the test specimen to the minimum allowable manufacturing thickness.

This correction factor is applicable only to metal structures. For other structures, use $K_{min} = 1$.

4.4.2 Correction factor for adjacent structures, K_{adj}

4.4.2.1 Generally speaking, during static qualification tests, the influence of adjacent structures in flight configuration should be simulated. In this case, take $K_{adj} = 1$.

4.4.2.2 When the influence of adjacent structures cannot be simulated correctly by the test facility, use a correction factor K_{adj}. The authority in charge of the structure shall deduce this factor by comparing results of two calculations made from the theoretical model.

4.4.2.3 Make the first calculation using boundary conditions of the test configuration and for each area, determine the stress σ_{test}.

4.4.2.4 Make the second calculation using boundary conditions of the flight configuration and determine the stress σ_{flight}.

4.4.2.5 The factor K_{adj} is determined by:

$$K_{adj} = \frac{\sigma_{flight}}{\sigma_{test}}$$

If, as a result $K_{adj} < 1$, use $K_{adj} = 1$.

4.4.3 Correction factor for thermal gradients, K_T

This factor is the ratio of the increase in stress resulting from the effect of the local thermal gradient to the stress corresponding to a zero thermal gradient.

4.4.4 Correction factor for temperature, K_θ

This factor takes into account the effect of temperature on the characteristics of the material. It is defined as the ratio of the value of the characteristic considered at the operating temperature of the flight structure to its value at the test temperature:

$$K_\theta = \frac{C_{\theta,\,\text{test}}}{C_{\theta,\,\text{flight}}}$$

where

$C_{\theta,\,\text{flight}}$ is a characteristic at the operating temperature;

$C_{\theta,\,\text{test}}$ is a characteristic at the test temperature.

4.4.5 Correction factor for dispersions, K_σ

This factor takes into account the effect of dispersions on Young's modulus, allowable stresses, and geometry on the wrinkling strength, compression strength, and tensile strength of the structure at the ambient temperature. For a characteristic C_i acting in a given failure mode:

$$K_\sigma = \frac{f\left(C_{i,\,\text{test}}\right)}{f\left(C_{i,\,\text{min}}\right)}$$

where

$C_{i,\,\text{min}}$ is the minimum allowable value of the characteristic C_i at ambient temperature (20 °C);

$C_{i,\,\text{test}}$ is the value of characteristic C_i for the specimen subjected to the test at 20 °C;

$f(C_i)$ is the function which translates the effect of the given characteristics in the failure mode considered.

EXAMPLE $f(C_1) = C_1{}^2$, if the structure strength is proportional to the square of C_1 for the considered failure mode. This is the case for the buckling of a cylinder where the critical load is proportional to the square of the thickness. In this situation (use of the square of the thickness for K_σ), K_{min} equals 1 to avoid too much conservatism.

If several characteristics C_1, C_2, ..., C_n, act in the considered failure mode, they give the following formula:

$$K_\sigma = \frac{f\left(C_{1,\,\text{test}}\right)}{f\left(C_{1,\,\text{min}}\right)} \times \frac{f\left(C_{2,\,\text{test}}\right)}{f\left(C_{2,\,\text{min}}\right)} \times \cdots \times \frac{f\left(C_{n,\,\text{test}}\right)}{f\left(C_{n,\,\text{min}}\right)}$$

NOTE For metal structures, the minimum thickness is the minimum allowable manufacturing thickness.

4.4.6 Correction factor for geometric imperfections, K_{imp}

This factor takes into account the effect of imperfections on the buckling behaviour. The correction factor K_{imp} shall be computed with the following formula:

$$K_{\text{imp}} = \frac{F_{\text{m imp}}}{F_{\text{d imp}}}$$

where

$F_{\text{m imp}}$ is the computed buckling load of the structure in flight configuration taking into account measured imperfections;

$F_{\text{d imp}}$ is the computed buckling load of the structure with the imperfections considered in the justification file.

If the objective of the test is not to demonstrate buckling capabilities or if the structure is not imperfection-sensitive, then $K_{\text{imp}} = 1$.

4.5 Comparison of results

If the results of calculations of stress made for test conditions are significantly different from those made for flight conditions or if the corrected safety factor, J_C, reaches a non-credible value, other specific modes of tests and correction of design loads, i.e. other than those proposed in this document, may be used if they have been already established, justified and used.

4.6 Implementation of this document

The corrected external loading shall be determined for all the areas of the flight-type structure considered as critical according to calculations in view of probable failure modes.

The lowest value of P_Q shall be selected for qualification tests.