
Space systems — Oxygen safety —

Part 1:

**Design of oxygen systems
and components**

Systèmes spatiaux — Sécurité des systèmes d'oxygène —

Partie 1: Conception des systèmes d'oxygène et leurs composants



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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 22538-1 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

ISO 22538 consists of the following parts, under the general title *Space systems — Oxygen safety*:

- *Part 1: Design of oxygen systems and components*
- *Part 2: Selection of metallic materials for oxygen systems and components*
- *Part 3: Selection of non-metallic materials for oxygen systems and components*
- *Part 4: Hazards analyses for oxygen systems and components*

The following parts are under preparation:

- *Part 5: Operational and emergency procedures*
- *Part 6: Facility planning and implementation*

Space systems — Oxygen safety —

Part 1: Design of oxygen systems and components

1 Scope

This part of ISO 22538 describes a process for the design of oxygen systems and their components. This part of ISO 22538 applies equally to ground support equipment, launch vehicles and spacecraft.

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 22538-2, *Space systems — Oxygen safety — Part 2: Selection of metallic materials for oxygen systems and components*

ISO 22538-3, *Space systems — Oxygen safety — Part 3: Selection of non-metallic materials for oxygen systems and components*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

3.1.1

direct oxygen service

service in which materials and components are in direct contact with oxygen during normal operations

3.1.2

indirect oxygen service

service in which materials and components are not normally in direct contact with oxygen but might be as a result of a malfunction, operator error or process disturbance

3.1.3

oxygen-enriched atmosphere

mixture (gas or liquid) that contains more than 25 volume percent oxygen

3.1.4

qualified technical personnel

persons such as engineers and chemists who, by virtue of education, training or experience, know how to apply physical and chemical principles involved in the reactions between oxygen and other materials

3.2 Abbreviated terms

CDR	critical design review
EPR	emergency procedures review
FMECA	failure modes and effects criticality analysis
GOX	gaseous oxygen
LOX	liquid oxygen
ORI	operational readiness inspection
PCTFE	polychlorotrifluoroethylene
PDR	preliminary design review
PTFE	polytetrafluoroethylene
SSA/SR	system safety analysis/safety review
TRR	test readiness review

4 Design approach

4.1 General

Oxygen is chemically stable and a strong oxidizer that supports combustion. It is not shock sensitive and is not flammable. Oxygen is reactive at ambient conditions and its reactivity increases with increasing pressure, temperature and concentration. Before embarking on a new task, it is important that designers, customers and operators understand the risks associated with oxygen systems.

4.2 Design specifications

Each new design project begins with specifications for the requested item. It is important that these specifications do not create an unnecessary risk for personnel or equipment. Most materials are flammable in high-pressure oxygen. An oxygen system designer shall understand that oxygen, fuel and a source of ignition are all that is necessary to start and propagate a fire. Many materials are combustible in oxygen-enriched environments and reactivity is generally increased with increasing temperature and pressure; therefore, materials selection criteria are critical in achieving a successful final product. The designer shall attempt to avoid using flammable materials; however, many materials that are flammable at operating conditions can be safely used in some applications by carefully avoiding ignition sources. The design shall never compromise safety to reduce costs.

4.3 Design reviews

4.3.1 General

In addition to the standard practice of reviewing functional operation, component ignition and combustion in oxygen-enriched environments shall also be assessed. The overall design process shall reduce hazards associated with component ignition and combustion. Before constructing oxygen facilities, equipment and systems, the design safety shall be approved by the designated installation safety authority or other approval points. The safety assessment process shall be integrated into the overall facility design review process. Each design review phase shall evaluate the safety aspects of the project according to its level of completion.

Reviews of the final drawings, designs, structures, and flow and containment systems shall include a safety assessment to identify potential system hazards and compliance with the proper regulatory organizations. The safety assessment shall also include the safety history of the system hardware. Such histories can identify equipment failures that may create hazardous conditions when the equipment is integrated.

All the procedures described in the following section refer to the design of both components and systems for oxygen use. The design reviews ultimately need to address all design aspects down to the individual part level because all parts pose potential hazards in oxygen service.

4.3.2 Preliminary design review (PDR)

A preliminary review shall be conducted on all materials and specifications.

4.3.3 Integrated failure modes and effects criticality analysis (FMECA) and hazard analysis

FMECA reviews each hardware item and analyses it for each possible single-point failure mode and single-barrier failure and their worst-case effects on the entire system. A FMECA will also include the results of the oxygen hazards analysis.

The interdependencies of all components shall be addressed and any single-point failures and the result of single-barrier failures shall be noted in a summary list of action items for correction. Single-barrier failures are often overlooked, but the potential for component-part failures, such as diaphragm failures, can cause hazardous oxygen-enriched environments and may cause a substantially increased risk of ignition near electrical components.

Attempting to correct single-point failures simply through procedural actions is not a reliable method. In addition, the FMECA shall consider the effects of failures in both static and dynamic operating conditions. When performed early in the design phase, this analysis greatly assists the designer in ensuring reliable systems. The FMECA shall be performed before fabrication of the component or system.

4.3.4 Systems and subsystems hazards analysis

The hazards analysis shall identify any conditions that could possibly cause death, injury or damage to the facility and surrounding property. It shall also

- a) include the effects of component and assembly single-point failures,
- b) review all ignition modes for all components and assemblies,
- c) include hazards associated with contamination,
- d) review secondary hazards, such as leakage to electrical equipment,
- e) consider the effects of maintenance procedures on safety and performance, and
- f) review toxicity concerns, especially for breathing oxygen.

4.3.5 Critical design review (CDR)

The final design review shall be held after all preliminary analyses have been completed and the action items from these analyses have been resolved. In this review, the final fabrication drawings and the supporting calculations are reviewed and all final action items resolved before authorizing fabrication and use.

4.3.6 System safety analysis/safety review (SSA/SR)

All safety aspects, including oxygen hazards, shall be reviewed to ensure the integrated design solution does not present unacceptable risks to personnel and property.

4.3.7 Other reviews

In addition to the PDR, FMECA, CDR and SSA/SR, the reviews below may be conducted as needed.

- a) Test readiness review (TRR): Operational procedures, along with instrumentation and control systems, shall be evaluated for their capacity to provide the required safety. Equipment performance shall be verified by analysis or by certification testing. It may be necessary to develop special procedures to counter hazardous conditions.
- b) Emergency procedures review (EPR): The safety of personnel at or near oxygen systems shall be carefully reviewed together with emergency procedures in the earliest planning and design stages. Advanced planning for a variety of emergencies, such as fires and explosions, shall be undertaken so that the first priority is to reduce any risk to life.
- c) Operational readiness inspection (ORI): An ORI may be required for any major facility change. Oxygen hazards shall be specifically reviewed for compliance with basic safety requirements.

4.4 Component and system testing

4.4.1 Intent/compliance

The intent of component and system testing is to ensure the integrity of equipment for its intended use. A wide variety of tests may be required, depending upon the critical nature of the equipment and whether or not it is flight-rated hardware. Compliance with safety programmes for pressure vessels and pressurized systems is required.

4.4.2 Prototype development testing

Initial testing is often best performed with inert fluids or gases; however, acceptance tests of the final hardware configuration shall be conducted with clean oxygen and parts cleaned for oxygen service. Testing with oxygen shall begin only after an oxygen hazards analysis has been performed on the specific test hardware.

Engineering development testing is intended to verify safe and reliable operation over a realistic range of operating conditions. It includes pressure integrity tests, assembly leak tests and configurational tests.

Consider worst-case operating tests to re-evaluate limited design margins, single-point failures and any uncertainties in the design criteria.

Life-cycle and flow tests are important in this phase of testing. Life-cycle tests shall be performed to determine the safety and longevity of systems components. The components shall be tested in each operational mode with the number of cycles based on the anticipated end-use. These do not constitute qualification, life-cycle or pressure qualification (proof) tests.

4.4.3 Qualification and acceptance testing

Test requirements will vary for each component or assembly to be tested. The equipment supplier, test facility personnel and end-user shall develop a joint test programme to verify function and oxygen compatibility.

5 Design for high-pressure and high-temperature gaseous oxygen systems

5.1 Design features

Design features, such as physical design of components and the component location in the system, shall be effectively coupled with proper materials selection to achieve safe operations. Evaluation of such design features shall begin with the preliminary design reviews.