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Space systems — Oxygen safety —

Part 4:
Hazards analyses for oxygen systems and components

Systèmes spatiaux — Sécurité des systèmes d'oxygène —

Partie 4: Analyse des dangers 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 22538-4 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*

INTERNATIONAL STANDARD **ISO 22538-4:2007(E)**

Space systems — Oxygen safety —

Part 4:
Hazards analyses for oxygen systems and components

1 Scope

This part of ISO 22538 provides a process for conducting hazards analyses on parts, components and systems in oxygen and oxygen-enriched environments. This part of ISO 22538 identifies processes that may be used on 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.

NASA TM 104823, *Guide for Oxygen Hazards Analyses on Components and Systems*

3 Terms and definitions

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

3.1
auto-ignition temperature
temperature at which a material will spontaneously ignite in oxygen under specific test conditions

3.2
hazard
source of danger, which could harm property or personnel

3.3
impact-ignition resistance
resistance of a material to ignition when struck by an object in an oxygen atmosphere under specific test conditions

3.4
ignition temperature
temperature at which a material will ignite under specific test conditions

3.5
non-metallic material
any material other than a metal, or any composite in which the metal is not the most easily ignited component and for which the individual constituents cannot be evaluated independently

3.6
oxygen compatibility
ability of a material to coexist with oxygen and a potential source of ignition at an expected pressure and temperature

3.7
oxygen-enriched atmosphere
any gas or liquid that contains more than 25 volume percent oxygen

3.8
risk
probability of loss or injury from a hazard

4 General

Since most materials will burn in oxygen-enriched atmospheres, hazards are always present when using oxygen. Most materials will ignite at lower temperatures in an oxygen-enriched atmosphere than in air. Once ignited, combustion rates are greater in the oxygen-enriched atmosphere. Many metals burn violently in an oxygen-enriched atmosphere. Lubricants, tapes, gaskets, fuels and solvents can increase the probability of ignition in oxygen systems. However, these hazards do not preclude the use of oxygen. Oxygen may be used safely if all materials in the system are not flammable in the end-use environment, or if ignition sources are identified and controlled. These ignition and combustion hazards necessitate a proper hazards analysis before introducing a material or component into oxygen service.

This part of ISO 22538 describes a method for analysing the hazards of components and systems exposed to oxygen-enriched environments. The oxygen hazards analysis is a useful tool for oxygen system designers, system engineers and facility managers. Problem areas shall be identified before oxygen is introduced into the system, thus preventing damage to hardware and possible injury or loss of life.

Annex A provides a list of typical components particularly susceptible to ignition mechanisms that are found in oxygen systems.

5 Approach

A hazards analysis of an oxygen component or system shall be approached as shown in Figure 1. The oxygen application and the scope of the investigation shall first be determined, and then a team shall be assembled to conduct the analysis. Information shall be collected on the materials, components and the worst-case operating conditions.

A fire will not usually occur in any environment unless the construction materials of the system or component are flammable and a credible ignition mechanism is present. The flammability of the material is first reviewed to determine if any fire hazards exist under the worst-case operating conditions. If the material is flammable, then the possible ignition mechanisms are reviewed to determine which are credible. If data for the particular ignition mechanism and the material under consideration are not available, appropriate material tests are conducted. Finally, the secondary and reaction effects are evaluated to determine what effect an ignition and possible combustion would have on the system and the facility.

It is necessary that use of an oxygen hazards analysis as a tool be properly documented from the beginning. A typical oxygen hazards analysis summary (see Annex B) contains the component designation (which indicates the materials of construction including soft goods), the possible ignition mechanisms, the probability of each ignition mechanism, the results of the secondary effects analysis and the reaction effects assessment. The documentation also includes recommendations for further testing, if needed, stipulations on use and any additional safety precautions.

See NASA TM 104823.

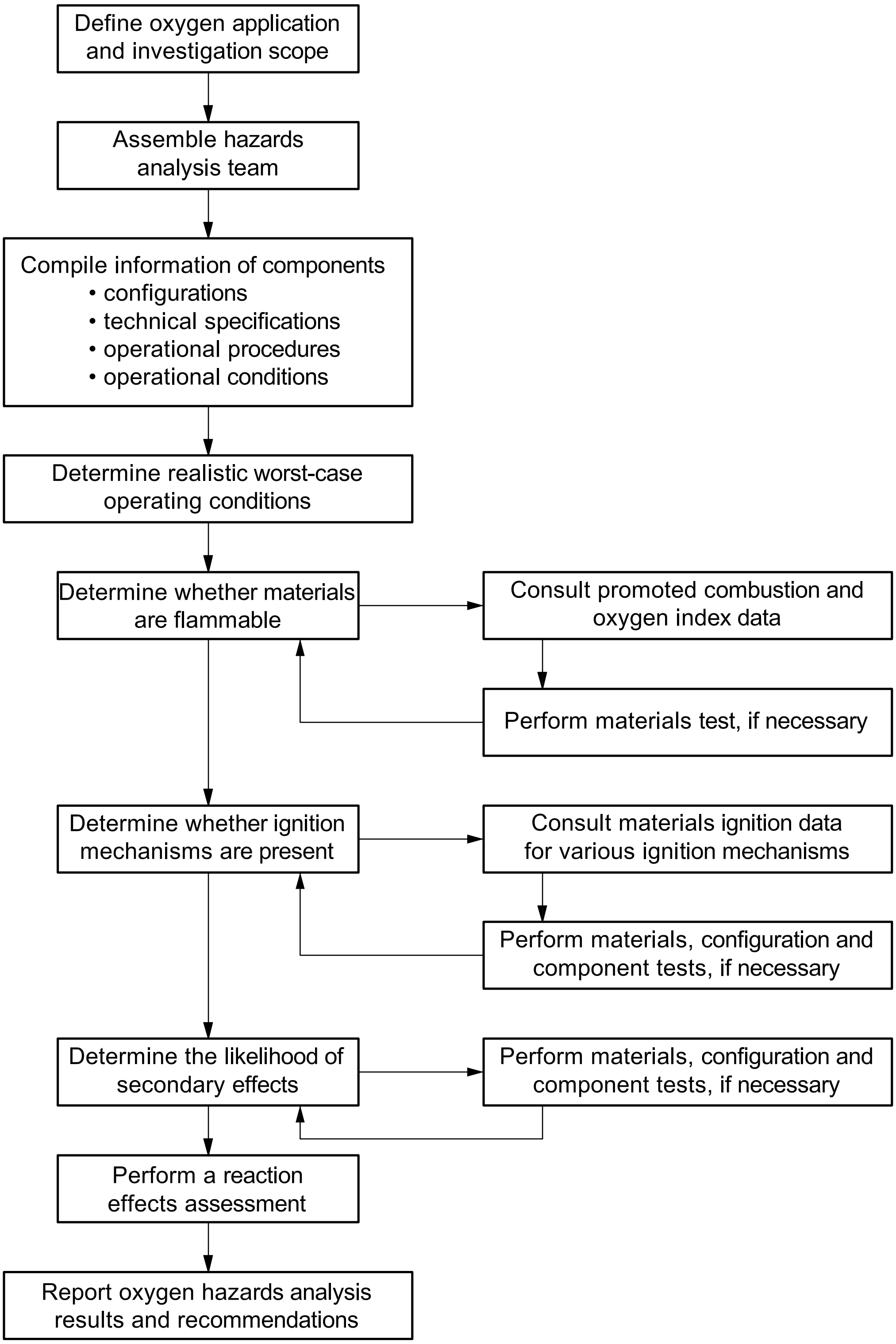

Figure 1 — Approach to oxygen hazards analysis

6 Procedures

6.1 Oxygen application and investigative scope

The oxygen application and investigative scope are first determined to provide the basis for choosing the oxygen hazards analysis team and for conducting the analysis.

6.2 Oxygen hazards analysis team

An oxygen hazards analysis team consists of, at a minimum:

- personnel with expertise in mechanical design;
- metals ignition and combustion;
- non-metals ignitions and combustion;
- component testing (with emphasis on oxygen systems).

Depending on the system, personnel with expertise in electrical design, cryogenic fluids, materials and chemistry may also be included.

6.3 Component/system information

Information on each component in the system is obtained, including

- materials of construction (including soft goods and lubricants),
- drawings showing the cross-section drawings of each component, particularly fluid flow paths and the locations of the soft goods, and
- a fluid system schematic.

The cross-section of the component shall be used to locate and identify all the soft goods. If the cross-sectional view of the component is of poor quality or unclear, a disassembled component complete with soft goods is sometimes useful. All materials of construction shall be identified. The flow path shall also be identified, along with all oxygen-wetted materials.

6.4 Worst-case operating conditions

The worst-case operating conditions that the component may undergo are determined. This information shall be used to evaluate the materials of construction for resistance to ignition and combustion, and it includes maximum use pressures, temperatures and flow rates. Pressures and temperatures are important because materials flammability is often a function of these two parameters. Flow rates are important because they affect the particle impact and adiabatic compression ignition mechanisms.

6.5 Material flammability

The materials used in the components and systems are evaluated to determine if they are flammable at the worst-case operating conditions. If information on a material for the worst-case operating conditions cannot be located, tests shall be conducted to obtain this information. If the materials and components are determined to be non-flammable, the ignition mechanisms need not be analysed for that component. The oxygen hazard analysis summary (see Annex B) is updated with the results, using

- "N" for non-flammable, or
- "F" for flammable.

6.6 Ignition mechanisms

6.6.1 General

An ignition survey is performed for each component found to have materials that are flammable under use conditions. Each ignition mechanism shall be evaluated to determine if it exists in the component and the likelihood that it will cause an ignition. The results of the analysis for each ignition mechanism are documented on the oxygen hazards analysis chart (see Annex B). Ratings for the ignition mechanism are

- "0" almost impossible,
- "1" remotely possible,
- "2" possible,
- "3" probable,
- "4" highly probable.

6.6.2 Frictional heating

Parts of a component or system may rub against one another with enough force or velocity to raise any one part to its ignition temperature at the given oxygen pressure and concentration.

EXAMPLE Rotating or oscillating equipment and chattering relief valves.

6.6.3 Adiabatic compression

High temperatures are generated if a gas is rapidly compressed. These high temperatures can readily ignite polymers or flammable contaminants.

EXAMPLE Downstream valve or flexible hose with a polymer liner in a dead-ended high-pressure oxygen manifold.

6.6.4 Mechanical impact

An object with a large mass or momentum striking a material may cause mechanical deformation and expose fresh surfaces, thus producing ignition of the material.

EXAMPLE A poppet of a solenoid-operated valve impacting the polymer seat.

6.6.5 Particle impact

Combustible particles impinging on materials at higher velocities in oxygen-enriched environments may cause ignition. The size of particles, flow velocity and temperature are among the variables that affect the ignition by particle impact

EXAMPLE Sonic-velocity gas through an orifice accelerating particles into a valve housing.

6.6.6 Mechanical stress or vibration

Materials that are poor heat conductors (such as polymers) may reach their ignition temperatures when stressed or vibrated.

EXAMPLE Gaskets that protrude inside piping.

6.6.7 Static discharge

Discharges of static electricity may produce high temperatures, sometimes high enough to cause a material to reach its ignition temperature.

EXAMPLE The accumulation of electrostatic charges created by the friction of dry oxygen flowing over non-metallic materials.

6.6.8 Electric arc

Electric arcs may provide the energy to ignite materials in the presence of oxygen.

EXAMPLE An insulated heater short-circuiting and arcing through its sheath to the oxygen.

6.6.9 Chemical reaction

An unrelated chemical reaction can produce sufficient heat to ignite materials in the presence of oxygen.

EXAMPLE A chemical process that generates elevated temperatures, oxygen-generating systems and the ignition of metals at high temperatures.

6.6.10 Resonance

Acoustic oscillations within resonant cavities cause a rapid gas temperature rise. The rise is rapid and achieves higher values when particles are present. Ignition may result if the heat generated is not rapidly dissipated.

EXAMPLE Gas flow into a tee and out of a branch port such that the remaining closed port forms a resonant chamber.

6.6.11 Flow friction

Small, high-pressure leaks past polymer seals can create friction and localized heating of the polymer in the gas flow.

EXAMPLE A small, high-pressure leak past a polymer seat in a gaseous oxygen valve.

6.6.12 Kindling chain

Ignition in one part of a component can, in turn, kindle an ignition in another part of the same component and lead to a burn-through of the component. This is especially true of ignited polymer pieces kindling other flammable polymer or metal pieces in a component.

EXAMPLE A polymer seat in a valve or regulator igniting and burning the surrounding metallic body.

6.6.13 Other ignition mechanisms

Other ignition mechanisms may be analysed that are specific to the component configuration or application. All potential sources of heat shall be evaluated as potential ignition sources.

6.7 Secondary effects analysis

After the ignition mechanisms have been surveyed, the secondary effects are analysed. This analysis shall address the effects of failures that are not ignition-related but may create an ignition hazard in a nearby component, such as an external leak caused by normal seal wear. Ratings for secondary effects analysis are

- "+" further analysis of affected components necessary, and
- "–" no further analysis needed.

See Annex B for the way in which the findings are recorded.

6.8 Reaction effects analysis

Finally, a reaction effects assessment is performed and documented. This is an assessment of the effect if a component fails or is ignited and is useful for making judgments on the safe use of a component. The reaction effects assessment would then help determine whether the component can be safely used. The ratings are as follows:

- "A" negligible, no loss of equipment or life;
- "B" marginal, equipment is damaged, but no lives are lost;
- "C" critical, loss of test data and damage to equipment, but no loss of life;
- "D" catastrophic, loss of equipment and life.

See Annex B for the way in which the findings are recorded.

Annex A
(informative)

High-risk components

Many of the typical components found in oxygen systems are particularly susceptible to one or more of the twelve possible ignition mechanisms. The following is a list of some of these components and the associated ignition mechanisms:

a) ball valve: particle generation (particle impact) and quick-opening (adiabatic compression);

b) butterfly valve: impingement even when fully open (particle impact);

c) check valve: chattering (mechanical impact/frictional heating);

d) filter: pneumatic impact of contaminants on the filter element;

e) fittings: particulate introduced into the system during assembly (particle impact);

f) flex hose: susceptible to adiabatic compression when dead-ended;

g) globe valve: impingement even when fully open (particle impact);

h) lubricants: hydrocarbon or silicone based materials (pneumatic impact and mechanical impact);

i) regulator: mechanical impact and high velocities generated (particle impact);

j) relief valve: chattering (mechanical impact or frictional heating);

k) soft goods: impingement on polymers in gas stream (pneumatic impact and mechanical impact).

Most ignition mechanisms for the above components can be eliminated or minimized by proper material selection, system design and operational constraints.

Annex B
(informative)

Example of oxygen hazards analysis chart on a PTFE-lined flexible hose

Airlock test system Media: GOX Maximum temperature: 46 °C (115 °F) Maximum pressure: 34 MPa (5 500 psi)	Metals	Soft goods	Frictional compression	Adiabatic compression	Mechanical impact	Particle impact	Mechanical stress	Static discharge	Electrical arc	Chemical reaction	Contamination	Flow friction	Kindling chain	Secondary effect	Reaction effect
Flexhose, hose assembly	F [a]	F [b]	0	4 [c]	0	0	0	0	0	0	0 [d]	1 [e]	4	+ [f]	D

NOTE 1 Material flammability
F = flammable
N = non-flammable

NOTE 2 Ignition hazards (see 6.6.1)
0 = almost impossible
1 = remotely possible
2 = possible
3 = probable
4 = highly probable

NOTE 3 Secondary effect (see 6.7)
+ = analysis of affected components needed
− = no further analysis needed

NOTE 4 Reaction effect (see 6.8)
A = negligible
B = marginal
C = critical
D = catastrophic

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[a] All metal parts are made from a 300 series stainless steel or heat-treated 17-4PH. This material is considered flammable in these conditions.

[b] Inner hose is made of seamless, white, virgin polytetrafluoroethylene with no carbon additives. This material is considered flammable in these conditions.

[c] Polytetrafluoroethylene-lined flexible hoses have ignited at pressures as low as 3,4 MPa when impacted in times less than 0,5 s. It is recommended to ensure that hoses are not “dead-ended” (e.g. connected directly to a closed valve) or that pressurization times of hoses are greater than 2 s.

[d] This assumes that the hoses are cleaned to 300A and that clean assembly procedures are followed.

[e] Leaks past polymer seats and seals have been known to cause fires in oxygen systems. It is recommended to quickly repair leaks across polymer seats and seals.

[f] Consider the effect of shedding polytetrafluoroethylene particulate on downstream components.

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