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Space systems — Safety and compatibility of materials —

Part 1:
Determination of upward flammability of materials

Systèmes spatiaux — Sécurité et compatibilité des matériaux —

Partie 1: Détermination de l'inflammabilité verticale des matériaux

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Foreword

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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).

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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 14624-1:2003), which has been technically revised.

The main changes are as follows:

- updated 6.5 "Bare nickel-chromium wire 0,81 mm (0,5 mm^2 diameter)";
- updated annexes;
- updated the Bibliography.

A list of all parts in the ISO 14624 series can be found on the ISO website.

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.

Introduction

In this document, the following verbal forms are used:

- "shall" indicates a requirement;
- "should" indicates a recommendation;
- "may" indicates a permission;
- "can" indicates a possibility or a capability.

Recommended criteria are, while not mandatory, considered to be of primary importance in providing serviceable economical and practical designs. Deviations from the recommended criteria may be made only after careful consideration, extensive testing and thorough service evaluation have shown an alternative method to be satisfactory.

Space systems — Safety and compatibility of materials —

Part 1:
Determination of upward flammability of materials

1 Scope

This document specifies a method for the determination of the flammability of aerospace materials by upward flame propagation. This test determines if a material, when exposed to a standard ignition source, will self-extinguish and not transfer burning debris which can ignite adjacent materials.

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/

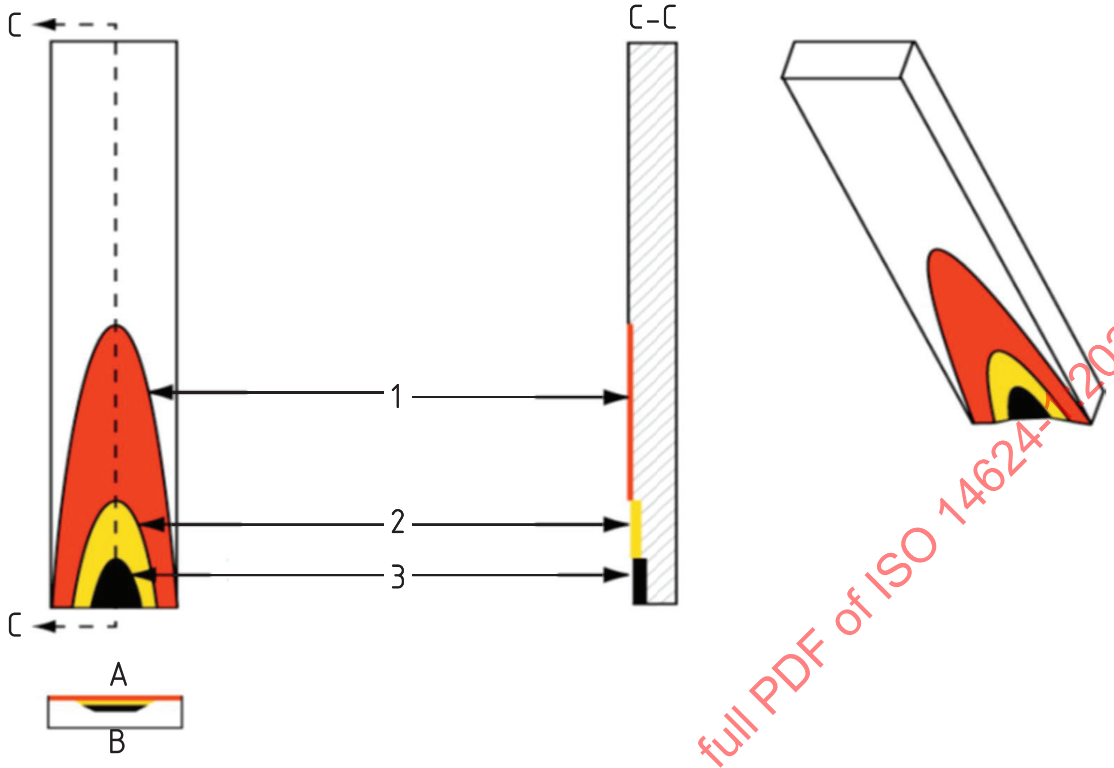
3.1
ambient conditions
test environment with an oxygen concentration of 20,9 % ± 0,2 %, a pressure of 101,4 kPa ± 5 kPa, and a temperature of 23 °C ± 5 °C

3.2
burn length
distance from the bottom of the specimen to the farthest evidence of flame consumption damage or flame attachment point to the test specimen due to flame as determined by visual observation, visual/physical post-test examination, video of burn, and/or other means

Note 1 to entry: See Table 1 and Figure 1. The burn length distance includes areas of partial or complete combustion, charring or embrittlement, but does not include heat affected areas which can have been damaged only by the heat of the flames emanating from sample consumption below. Heat affected areas appear as sooted, stained, warped or discoloured, or areas where the material has shrunk or melted away from the heat. In some cases, the flame can propagate beyond the farthest visual evidence of damage to the test specimen. Typical material burn model depicted in Figure 1, some materials can show multiple flame fronts and/or other variations.

Table 1 — Burn length assessment characteristics and techniques summary

Burn length / Flame consumption damage	Heat affected damage area	Burn length determination techniques
Complete combustion	Sooted	Visual observation
Partial combustion	Stained	Visual post-test examination
Charring	Warped	Physical post-test examination
Embrittlement	Melted away from heat	Video of burn
Furthest flame attachment point	Shrunk away from heat	Other means



Key

1	heat affected damaged area
2	flame consumption damaged area
3	ignitor influence area
A	front
B	back
C	cross section of sample

Figure 1 — Typical material burn depiction, typical sample consumed area and heat affected damage area

3.3
burn propagation time
time that elapses from ignition of the specimen until vertical flame propagation stops

3.4
chemical ignitor
ignitor validated to strict specifications in order to produce a flame that meets all the requirements for an ignition source

Note 1 to entry: The requirements for the ignition source are specified in 6.3. See Annex A for one method of producing a chemical ignitor.

3.5
good laboratory practice
GLP
practice which involves the testing of standard reference materials to verify data accuracy and repeatability

Note 1 to entry: In addition, the test facility shall successfully demonstrate the ability to obtain repeatable data when testing a selected material. The authority having jurisdiction shall choose appropriate GLP materials and shall determine the frequency of testing these materials for its test facilities.

3.6
maximum allowable oxygen concentration
MOC

highest oxygen concentration (volume fraction), in an oxygen/nitrogen atmosphere, at which at least five specimens pass the acceptance criteria of this test, without a failure, and one or more of the specimens fail the test if the oxygen concentration is increased by an arbitrary increment, typically 1 %

Note 1 to entry: See Annexes B, C, D and ISO/TS 16697 for the threshold approximation procedure.

3.7
self-extinguish
phenomenon in which the *burn length* (3.2) on a *standard test specimen* (3.8) does not exceed 150 mm

3.8
standard test specimen
representative part, taken from a quantity of material or fabricated per required preparation method, meeting the following minimum dimensions:

a) length = 300 mm

b) width = 60 mm [75 mm for *thin-film specimen* (3.9)]

c) thickness – use thickness (minimum thickness of the material in its intended use application, but not to exceed 25 mm, excluding substrate)

Note 1 to entry: The required test specimen exposed width is defined in 6.6.

3.9
thin-film specimen
specimen with a total thickness of less than 0,25 mm

Note 1 to entry: Fabrics or coatings applied to a substrate are not considered thin-film specimens.

3.10
transfer of burning debris
movement of any material from a burning specimen with sufficient energy to ignite adjacent material

Note 1 to entry: The sheet of paper below the test specimen is specified in 6.8.

3.11
upward limiting oxygen index
ULOI

oxygen concentration where approximately 50 % of samples fail the test criteria

3.12
worst-case test configuration
test configuration that simulates worst-case anticipated use conditions including material thickness, test pressure, and oxygen concentration

Note 1 to entry: Worst-case represents the cumulative effect of multiple factors that increase the probability that a material is flammable; can involve smallest thickness for use without a substrate or sufficient thickness to prevent heat loss from a substrate, increased surface area (such as mesh configuration), irregular surface configuration, increased oxygen concentration, increased pressure, increased temperature, etc. Furthermore, oxygen concentration (volume fraction) is typically the primary driver of flammability and should be prioritized over pressure when examining for worst-case conditions.

3.13
worst-case use thickness
material thickness that, for a specific application, makes the material most flammable

Note 1 to entry: Worst-case use thickness can involve the smallest thickness for use without a substrate or sufficient thickness to prevent heat loss from a substrate and increased surface area (such as mesh configuration), irregular surface configuration.

4 Principle

An ignition source with specific characteristics is applied for a defined period of time to the lower end of a standard test specimen of material oriented vertically in a test chamber or fume hood containing a specific test environment. The post-test burn lengths for at least five standard-sized specimens are recorded. Materials are considered flammable in the test conditions if at least one standard test specimen burns more than 150 mm. In addition, the ignited specimens shall not ignite the paper (produce combustion) below the test samples, which indicates that the transfer of burning debris has sufficient energy to ignite adjacent materials. If, during a test, the paper used as an indication of the transfer of burning debris ignites because of burning debris, subsequent burns during the same material test should be conducted without paper to eliminate burning paper interference.

Failure of any one specimen constitutes failure of the material in that test environment.

Materials shall be tested in the worst-case test configuration. If the worst-case oxygen concentration is uncertain, determination of the maximum allowable oxygen concentration is recommended.

5 Reagents

5.1 Test gases. The test atmosphere shall consist of a mixture of oxygen and nitrogen, mixed thoroughly before testing a specimen. These gases can be premixed before introduction of the mixture into the test chamber, or the oxygen and nitrogen can be introduced separately into the test chamber, and then mixed inside the test chamber with a test specimen.

Oxygen gases used in test gas mixtures shall be verified to have a minimum purity of 99,5 % and moisture < 7 µl/l[1]. Nitrogen gases used in test gas mixtures shall be verified to have a minimum purity of 99,9 % and moisture <11,5 µl/l.

Also, the gas mixture shall be verified for conformity with the specification (including accuracy) for oxygen concentration to within +1 % −0 %. Pre and post-test gases are analysed for CO and CO_2 and post test results reported.

6 Test system

6.1 Test chamber, large enough so that complete combustion of the specimen can occur with no more than a 5 % relative depletion of oxygen concentration. In addition, the test chamber shall not interfere chemically or physically with the test.

6.2 Measuring devices, properly calibrated.

6.3 Chemical ignition source, meeting the following specifications in ambient conditions:

a) temperature:	1 100 °C ± 90 °C measured using a 0,81 mm (0,5 mm^2 diameter) exposed tip type K thermocouple;
b) burning duration:	25 s ± 5 s;
c) maximum visible flame height:	65 mm ± 6,5 mm.

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[1] 1 µl/l = 1 part per million (ppm). The use of “ppm” is deprecated.

Annex A provides a procedure for preparing, certifying and storing chemical ignitors.

NOTE This test method and the corresponding ignition source are designed to evaluate materials for use in spacecraft habitable environments with typical oxygen concentration ranges (19 % to 50 % volume fraction of oxygen). When evaluating environments outside of these typical ranges the standard ignition source cannot be adequate. In these cases, alternative ignition mechanisms can be utilized but test data is reported as a non ISO 14624-1 standard.

6.4 Power supply, capable of providing 15 A (root mean square), connected to a bare 0,81 mm diameter nickel-chromium wire (6.5) to initiate the igniter.

6.5 Bare nickel-chromium wire 0,81 mm (0,5 mm^2 diameter), with a nominal resistivity of 2 Ω·m to 2,5 Ω·m,3 m and of sufficient length to wrap three equally spaced turns around the chemical igniter.

6.6 Suitable specimen holder, capable of supporting the specimen in the vertical position

6.6.1 Standard test specimen holder (see Figure 2), allowing a minimum of 50 mm of the width of the specimen to be exposed and extending over the full length of the specimen. The test specimen exposed width for materials other than thin-film specimens shall be 50 mm to 60 mm.

The bottom of the specimen holder shall be located at least 250 mm from the bottom of the test chamber.

6.6.2 Specimen holder for thin-film specimens, allowing at least 50 mm of the width of the specimen to be exposed and minimizing shrinkage of the test material away from the flame. The test specimen exposed width for thin films shall be between 75 mm to 85 mm.

NOTE When mounting thin films for testing, minimized tension across the material reduces test stand influence. When the influence of the test stand on the results is of concern, large thin films measuring (300 mm x 200 mm × the use thickness) can optionally be used, subject to the approval of the authority having jurisdiction.

Two types of specimen holder can be used:

a) a holder for a standard test specimen (see 6.6.1 and Figure 2), which employs three wing-nut clamps or one long clamp;

b) a holder employing needle rakes to hold thin film specimens (see Figure 3).

6.7 Scale, attached to one side of the specimen holder, for measurement of the burn length.

6.8 Sheet of paper, mounted horizontally approximately 200 mm below the specimen holder, but 50 mm above the bottom of the test chamber, centred directly below the specimen. The paper shall be supported by a non-flammable, non-conducting material. The paper shall have the following characteristics:

a) dimensions: (200 mm ± 50 mm) × (300 mm ± 50 mm);

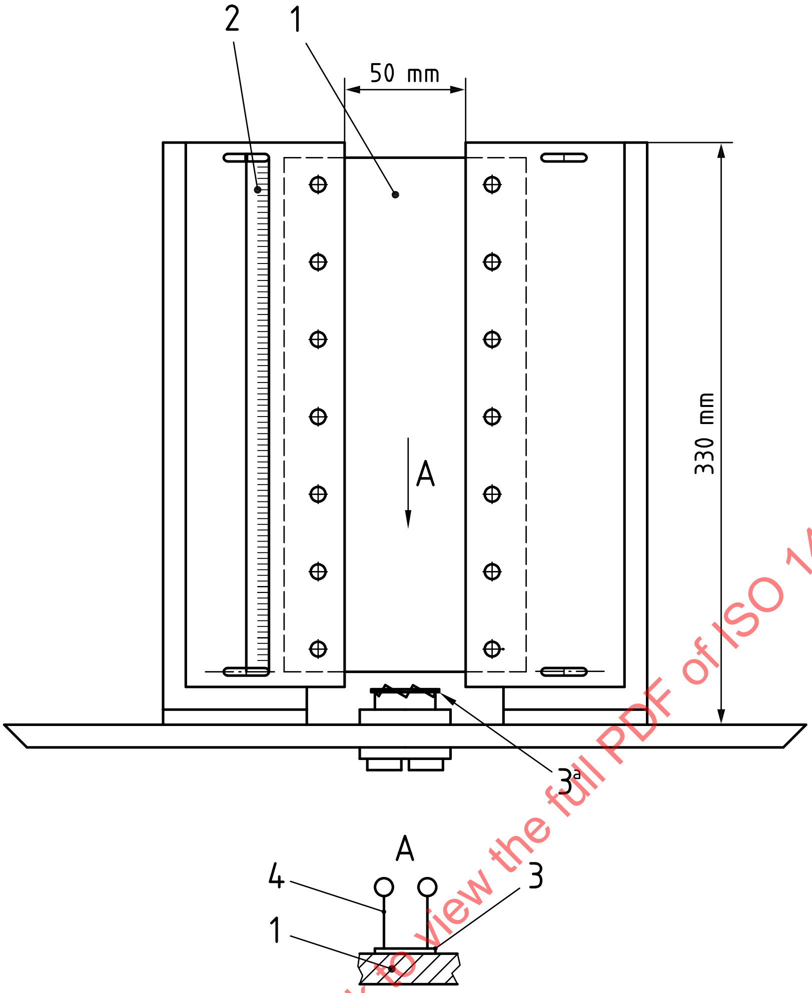
b) surface density: between 200 g/m^2 and 300 g/m^2;

c) type: chemical wood processed;

d) colour: uniformly white;

e) condition: clean, free from dirt spots, oil spots and foreign matter (lint, fuzz, etc.), free from holes, tears, cuts, folds and scuff marks, and containing no splices.

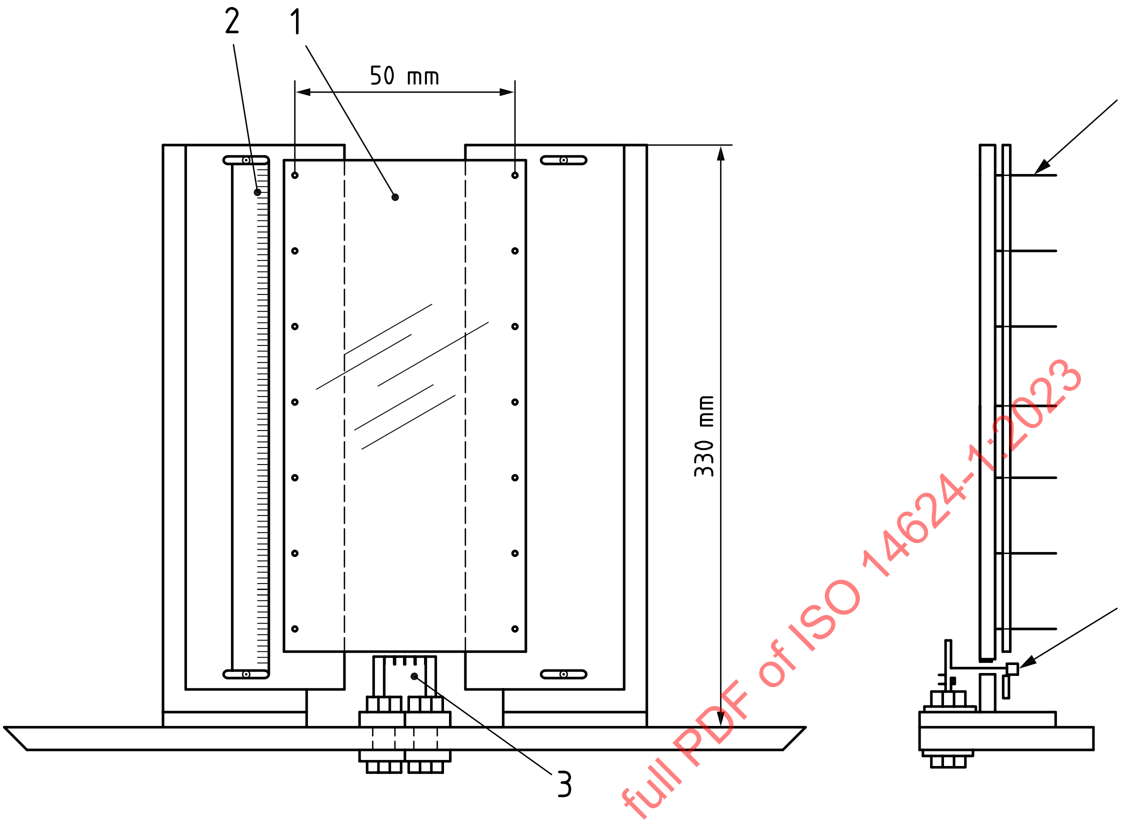
The sheet of paper is used to assess if burning debris from the specimen can cause ignition of adjacent materials.



Key

1	specimen
2	scale
3	ignitor
4	nickel-chrome wire
a	The ignitor is placed inside the coil.

Figure 2 — Standard test specimen holder



Key

1	specimen
2	scale
3	ignitor
4	needle

Figure 3 — Needle rake mount for thin-film specimens

7 Test specimens

7.1 Materials

The minimum quantities and dimensions of materials required to perform each test properly are summarized in Table 2. Actual test configurations and material quantities for material forms other than those listed (e.g. O-rings and other seals) shall be established and approved by the responsible procuring activity/user materials organization.

Table 2 — Minimum quantities of materials required for testing for each atmosphere

Form of material	Minimum quantity
Sheets	6 specimens measuring 300 mm × 65 mm × the required thickness
Thin films	6 specimens measuring 300 mm × 75 mm × the required thickness When the influence of the test stand on the results is of concern, large thin films measuring 300 mm × 200 mm × the required thickness can optionally be used, subject to the approval of the authority having jurisdiction.
Coatings	Sufficient to cover, at the required thickness, 6 substrates measuring 300 mm × 65 mm
Foams	6 specimens measuring 300 mm × 65 mm × the required thickness
Insulated wires	2 m in length

As a minimum, all materials used in testing shall meet or exceed user specifications.

Material and configured-system characteristics can be significantly compromised by sources of contamination, such as exposure to solvents, cleaning agents, abnormal temperatures, variations in humidity, environmental pollutants, particulates and handling. It is important that exposure of test material(s) to these and other contamination sources be sufficiently controlled to minimize variation in test results.

7.2 Reception and inspection of material

7.2.1 Receive and visually inspect the test material: when received, it shall be accompanied by proper identification and its thickness shall correspond to the specified worst-case use thickness. Any flaws shall be noted. Specimens should have been cleaned and dried to the end-use specifications prior to receipt at the test facility.

7.2.2 If required, prepare specimens to the proper dimensions, including worst-case use thickness.

7.2.3 If specimens are received with obvious contamination, clean them. All cleaning methods shall be approved by the test requester prior to use. Surface contamination should be removed by washing with deionized water and mild detergent, rinsing with deionized water, and drying with filtered nitrogen gas. As a minimum, particulates on the surfaces of solid porous specimens should be removed with filtered nitrogen gas.

7.2.4 After preparation and/or cleaning at the test facility, inspect the specimens to ensure that they are at the specified worst-case use thickness. Any flaws and any residual contamination shall be noted. If the flaws result from specimen preparation at the test facility, new specimens shall be prepared. Specimens shall be weighed and individually identified.

7.3 Preparation of test specimens

7.3.1 Sheet and other bulk-form specimens shall be cut to 300 mm × 65 mm in the worst-case use thickness. Materials, configurations and components that cannot be prepared to these requirements shall be tested in the configuration as purchased. Non-standard test specimens shall be mounted in the chamber in a manner that does not inhibit flame propagation.

Test specimens prepared from bulk materials shall be prepared in a manner that is representative of the material’s end usage configuration. Inherent variability in non-homogenous bulk materials should be considered when determining test specimen preparation methods.

7.3.2 Materials that require a cure shall be prepared in the worst-case use thickness and cured according to the requester's instructions. The specimens shall be cut to 300 mm × 65 mm.

7.3.3 Coatings or any viscous material that cannot be mounted for testing without a substrate shall be applied to the end-use substrate material in the worst-case use thickness. Aluminium substrates approximately 0,5 mm thick can be used if the end-use substrate is unknown or inappropriate. Any requested cures shall be performed. The specimens shall measure 300 mm × 65 mm. Coatings, films or adhesive backed tapes proposed for use on non-metallic surfaces shall be applied to the proposed non-metallic surface, in the worst-case use thickness.

7.3.4 Non-adhesive-backed hook-and-loop tapes shall be tested in the “as received” condition, unless otherwise noted by the requester. Adhesive-backed hook-and-loop tapes shall be applied to a 300 mm × 65 mm × 0,5 mm aluminium substrate. To ensure ignition of the tape backing, as opposed to the hooks or loops only, approximately 13 mm of the test specimen shall extend beyond the substrate.

7.3.5 Semi-solid materials shall be applied to a suitable non-combustible substrate such as glass-fibre cloth. Semi-solids shall be applied to the substrate as a uniform coat.

7.3.6 Liquid materials shall be tested using an appropriate standard test for determining the flash point of liquids.

7.3.7 Thin-film specimens shall be cut to 300 mm × 75 mm. Optionally, large thin films measuring 300 mm × 200 mm can be used, subject to the approval of the authority having jurisdiction, to reduce material shrinkage away from the flame.

8 Procedure

8.1 General

This test method shall be performed per the procedure specified in 8.2 to 8.4.

WARNING — Burning of materials can produce smoke and toxic gases and residues, which can affect the health of operators. Clear test area of smoke and fumes by suitable means. Ensure appropriate safety precautions are taken at all times.

8.2 Before testing

Before testing, observe the vertical surfaces of the test specimens and record any pertinent observations, such as imperfections, discolorations. Also record all other pertinent information (including oxygen concentration, specimen identification, and specimen pre-test mass and size). Photograph a typical pretest.

Maintain and verify the test system to be visibly clean, and all measuring devices to be in proper calibration.

The exposed centre section of standard-sized specimens shall be 50 mm wide. Do not overly stretched or tighten specimens, which would cause lines of horizontal stress. Mount thin films with 10 mm of slack in the width to allow for shrinkage.

Place the top point of the ignitor surface 6 mm ± 1 mm below the lower edge of the specimen parallel to the lower edge of the specimen and centred along the plane of the front surface of the specimen. Take care when testing materials on substrates to ensure that the ignitor is centred along the plane of the front surface of the specimen and not that of the substrate.

Position a sheet of paper centred 200 mm below the test specimen. Hold paper in place by a non-flammable, non-conducting screen material.

Video record all specimens during testing.

8.3 Test

8.3.1 Before ignition of chemical ignitor

Test five replicate test specimens.

Subject all specimens to vacuum for no less than 1 min, but no more than 3 min before introduction of the proper test atmosphere.

If vacuum exposure damages the test material, purging of the test chamber or gas supplementation can be used to achieve the required test atmosphere.

Expose specimens to the proper test atmosphere for a minimum of 3 min before ignition.

Prior to ignition, ensure that a homogenous mixture is achieved within the chamber.

Measure, verify and record the percentage oxygen concentration and the total pressure for each individual specimen.

Activate the recording device prior to activating the chemical ignitor. Activate the chemical ignitor.

8.3.2 After ignition of chemical ignitor

Immediately upon ignition of the chemical ignitor, turn off the power to the nickel-chromium wire. Activate the timing device used to measure the burn propagation time once specimen ignition is observed.

Retract ignitor from the test specimen once the ignitor extinguishes.

Observe the vertical surfaces of the specimen and record any pertinent observations. Record any flame jets or sparks emanating from the sample during the test. Observe the paper below the sample for any indications of ignition. Observe and record flames emanating from the paper below the specimen. Take post-test photographs.

8.4 After testing

After the test, record the final oxygen concentration, the burn length, and the post-test mass, and any abnormal occurrences. Take post-test photographs.

9 Accuracy

Measurements shall be made within the following tolerance limits:

a) absolute pressure: ±1 %;

b) oxygen concentration: ±0,5 %;

c) specimen width: ±5 %;

d) specimen length: ±20 %;

e) specimen mass: ±1 %;

f) burn length: ±10 mm.

10 Test report

10.1 Standard tests

The test report shall include details of the specimen identification, the specimen preparation, the specimen configuration, the test conditions, observations from the test, as well as pre and post-test photographs. Proper reporting of the test observations, such as the burn length, the transfer of burning debris, and other observations (especially of unusual behaviour) is critical. The test report shall be submitted to the authority having jurisdiction and/or the test requester.

10.2 Non-standard tests

When there is a deviation from standard test parameters, such as non-standard test specimen preparation, specimen dimensions, specimen orientation, test stand or ignition source, the test shall be identified as non-standard. In addition, all information in 10.1 shall be reported.

10.3 Good laboratory practice (GLP)

At least every 2 years, the test facility shall successfully demonstrate the ability to obtain accurate and repeatable data when testing selected materials. The authority having jurisdiction shall choose appropriate GLP materials for its test facilities.

Annex A
(informative)

Preparation and qualification of chemical ignitors

A.1 General

This annex provides one method of manufacturing chemical ignitors which produce a flame that meets the requirements for testing in atmospheres in which the oxygen concentrations are between 15 % and 50 %. Any ignition source meeting the criteria outlined in this document can be utilized.

A.2 Safety requirements

All personnel associated with the manufacturing of these ignitors should be familiar with the safety requirements associated with the materials and equipment used.

A.3 Materials

A.3.1 Hexamethylenetetramine (HMT), 98 %, or higher, pure reagent grade, in powder form, properly packaged and stored to prevent contamination by moisture.

A.3.2 Anhydrous sodium metasilicate, 98 %, or higher, pure reagent grade, in granule form, properly packaged and stored to prevent contamination by moisture.

A.3.3 Gum arabic (acacia), in powder form.

A.3.4 Deionized water, for mixing with the dry ingredients to form the ignitor dough.

A.3.5 Certified breathing air, used in the certification of the ignitors.

A.4 Equipment

A.4.1 Hammer mill, for grinding the dry components of the ignitor mixture.

A.4.2 Glove box with a temperature/humidity meter, used when grinding some of the dry ingredients.

NOTE Alternatively, ignitors can be manufactured in a fume hood if the relative humidity is lower than 20 %.

A.4.3 Bags, for storing the ground dry ingredients.

A.4.4 40-mesh (40 µm) screen, for sieving the ground dry ingredients.

A.4.5 Fume hood, used when grinding some of the dry ingredients, and for mixing the ignitor dough. The air flow rate in the fume hood should be at least 30 m/s.

A.4.6 Respirator with organic canisters, used when grinding the HMT.

A.4.7 250 ml burette, for holding the deionized water and gradually adding it to the mixture.

A.4.8 Heavy-duty electric mixer, for mixing the ignitor dough.

A.4.9 Spatula, for scraping the sides of the mixing bowl during preparation of the ignitor dough.

A.4.10 Plastic trays, non-stick, measuring approximately 76 mm × 380 mm × 1,5 mm, to catch the extruded ignitor dough and hold it while it dries.

A.4.11 Conveyor belt, to move the plastic trays at a constant rate so that the string of ignitor dough is not stretched or allowed to become too thick.

A.4.12 Extruder, for extruding the ignitor dough on to the plastic trays.

A.4.13 Cutting tools, for cutting the ignitor dough string to the proper lengths.

A.4.14 Drying racks, for holding the plastic trays containing the ignitor dough string.

A.4.15 Desiccator with desiccant, to ensure that the proper humidity is maintained during drying and storage of the ignitors.

A.4.16 Balance, for weighing the dried ignitors.

A.4.17 Corrugated plastic holder, used when cutting overweight dried ignitors to a length that ensures the correct mass.

A.4.18 Power supply, capable of providing 15 A (RMS), used in the certification of the ignitors.

A.4.19 Bare 20 AWG nickel-chromium wire, with a nominal resistivity of 2,3 Ω·m, used in the certification of the ignitors.

A.4.20 Graduated ruler, for measuring the length of the ignitors and the ignitor flame height during certification.

A.4.21 Test chamber (or fume hood), used during certification of the ignitors.

A.4.22 Calibrated stopwatch, for determining the burn time during certification of the ignitors.

A.4.23 Soft-bristled brush, for cleaning the ignitor coil between certification of individual ignitors.

A.4.24 Plastic container (box), for storing the ignitors.

A.4.25 Corrugated foam wrap, for wrapping the stored ignitors.

A.5 Grinding the ignitor-mix ingredients

A.5.1 To ensure a homogeneous mixture, grind the raw materials using a hammer mill. Grinding is not necessary for the gum arabic.

A.5.2 Grind the sodium metasilicate in a glove box, as follows. Place the hammer mill, the material to be ground and any other necessary tools inside the glove box. Attach a bag to the output end of the hammer mill with tape to capture the ground material. In addition, place a 40-mesh screen inside the hammer mill. Seal the glove box and, before grinding the material, purge the glove box with dry air for approximately 4 h or until the humidity inside the glove box is below 20 %.

A.5.3 Grind the material. Detach the bag from the hammer mill, seal the bag, place it inside another bag and seal the second bag.

A.5.4 Clean the hammer mill between the grinding of different materials.

A.5.5 Grind the HMT in a fume hood. The air flow rate in the fume hood should be at least 30 m/s, and a respirator with organic canisters should be worn by the operator. Follow the same procedures as when grinding the sodium metasilicate described in A.5.2 to A.5.4.

A.5.6 After grinding, store each material separately, suitably identified.

A.6 Weighing and mixing the ignitor-mix ingredients

A.6.1 To make a 400 g mixture, the following amounts of each solid ingredient are necessary:

a) (280,8 ± 0,2) g of HMT;

b) (105,2 ± 0,2) g of anhydrous sodium metasilicate;

c) (14,0 ± 0,2) g of gum arabic.

A.6.2 For other size batches, the mixture should be comprised of 70,2 % ± 0,1 % HMT, 26,3 % ± 0,1 % sodium metasilicate and 3,5 % ± 0,1 % gum arabic.

A.6.3 Carry out the weighing and mixing on the day of extrusion (do not mix the dry ingredients prior to the day of extrusion).

A.7 Adding water

A.7.1 Adding water and the subsequent works should be performed under the environment with humidity below 20 %. Pour 200 ml of deionized water at room temperature into a 250 ml burette.

A.7.2 Open the tap of the burette and allow approximately 10 ml of deionized water to flow into the mixing bowl of a heavy-duty electric mixer. Cool the mixing bowl using an iced water bath to absorb the heat generated by the mixture.

A.7.3 Place the dry ignitor mix in the mixing bowl. Ensure the ignitor mix is evenly distributed in the bowl.

A.7.4 Operating the electric mixer at low speed, slowly add deionized water to the mixture. Initially, the mixture is very wet. As the sodium metasilicate absorbs the water, the mixture starts to thicken and eventually achieves a dough-like consistency. This can take 20 min to 30 min, depending on the environmental conditions. During mixing, scrape the sides of the mixing bowl with a spatula.

A.7.5 As the proper dough-like consistency is achieved, the mixture starts to pull away from the sides of the bowl. When this occurs, stop adding water. Too much water causes the mixture to be too wet to extrude. Generally, 190 ml to 200 ml of deionized water is added from the burette to the mixture.

A.8 Extruding the ignitors

A.8.1 Extruding the ignitors is a three-person operation. One person places the plastic trays on the conveyor belt. Another person controls the process by adjusting the conveyor belt speed and the extruder controller speed, and cuts the extruded ignitor dough between trays. The third person removes the trays from the conveyor belt and places them in drying racks.

A.8.2 Turn on the conveyor belt and make any necessary adjustments to belt tension to prevent any belt hesitations. In addition, for a 400 g mixture, make sure that there are approximately 75 plastic trays next to the beginning of the conveyor belt. More is needed for a larger batch. Turn the conveyor belt off.

A.8.3 Assemble the extruder and fill with ignitor dough.

A.8.4 When extrusion starts, turn the conveyor belt on and be ready to place the plastic trays on the conveyor belt as the ignitor dough exits the extruder. Adjust the conveyor belt and extruder speed as required during this operation to ensure that the extruded ignitor dough comes out straight and unstretched. Cut the dough between trays, so that the trays can be placed individually in the drying racks.

A.8.5 After all the dough has been extruded onto the trays, and the trays removed to the drying racks, clean all the equipment.

A.9 Curing, cutting and weighing the ignitors

A.9.1 After all the ignitor dough has been extruded onto the plastic trays, place the ignitors in a well-ventilated area (relative humidity < 20 %) to dry. The igniters should be cut to the proper lengths once the dough is dry enough to cut. The dry time for the dough to be dry enough to cut can range from 24 h to 30 days.

A.9.2 Cut all the ignitor strings on the plastic trays to a length of 28 mm ± 3,2 mm. Continue to dry the cut ignitors under the conditions described in A.9.1 for another 6 months.

A.9.3 Transfer the ignitors from the plastic trays to a desiccator (relative humidity < 15 %). Place them directly on the desiccant bed.

A.9.4 Continue to dry the ignitors inside the desiccator. After approximately seven days, select ten ignitors and weigh them. The mass specification for the ignitors is 190 mg to 240 mg. If the mass of eight out of the ten ignitors is within the specified range, the final dried state has been reached, and the ignitors are ready for certification. If more than two ignitors weigh over 240 mg, continue to dry the ignitors.

A.9.5 If more drying time is required, as described in A.9.4, wait for 2 to 3 months, then select ten additional ignitors. If eight out of the ten meet the mass specification, the ignitors are ready for certification. Due to varying conditions in desiccators, this process can take as long as 9 to 12 months.

A.10 Certifying the ignitors

A.10.1 Weigh all the ignitors in the desiccator. If an ignitor weighs less than 190 mg, it is underweight, and should be discarded. If an ignitor weighs more than 240 mg, it can be cut down to 25 mm long to meet the mass specification. If the proper mass is not achieved within the length specification, the ignitor should be discarded. Cutting and weighing of the ignitors should be done in a dry environment (relative humidity < 20 %), since the ignitors absorb moisture when exposed to excess humidity. In addition, the ignitors should remain circular, and not flatten out while curing, in order to fit inside the ignition coil. To ensure this, ignitors should be placed in a rigid plastic corrugated holder while being cut.

A.10.2 To certify a 400 g mixture batch, randomly select a sample of 20 ignitors. If a larger mixture batch is made, the certification sample should be increased accordingly. The 20 ignitors selected should be tested for the peak flame temperature, burn time and peak flame height. Each ignitor tested should develop a flame temperature of 1 100 °C ± 90 °B. The ignitor flame should be sustained for 25 s ± 5 s with a peak flame height of 65 mm ± 6,5 mm. In addition, perform heat of combustion tests on 5 ignitors in accordance with ISO 1928. The gross heat of combustion of ignitors should be (20 440 ± 1 360) J/g.

A.10.3 Ignitors should be tested in certified breathing air at 100 kPa. The temperature should be measured by a type K thermocouple constructed with a 0,81 mm diameter wire extruding (10 ± 1) mm from its sheath. The head diameter of the thermocouple should be (1,0 ± 0,1) mm. The thermocouple wire should be centred geometrically 25 mm above the top of the ignitor. To initiate the ignitor, a power supply capable of providing 15 A (RMS) should be connected to a bare 20 American Wire Gauge nickel-chromium wire. The wire should have a nominal resistivity of 2,3 Ω·m and should have sufficient length to wrap three equally spaced turns around the ignitor. The nickel-chromium wire coil should be replaced before certifying each batch of ignitors. In addition, the length of the leads to the nickel-chromium wire coil should not exceed 32 mm to ensure proper ignition of the ignitor. A graduated ruler should be placed in the test chamber to measure the flame height.

A.10.4 Before starting the certification, ensure that the thermocouple wires are not touching each other, and that the thermocouple is in proper calibration.

A.10.5 To certify a batch of ignitors, perform the following steps for each of the 20 randomly selected ignitors.

a) Place the ignitor in the nickel-chromium wire coil.

b) Pressurize the test chamber to 100 kPa with certified breathing air.

c) Turn on the power to the ignitor. When ignition is accomplished, turn the power off.

d) Record the peak flame temperature (from the thermocouple), the burn time and the flame height. The time from the moment of ignition to the moment of flame extinction (burn time) should be obtained using a calibrated stopwatch. The flame height should be determined by measuring the maximum height of the flame to the apex. The flame can flutter for a few seconds. The flame height should be measured after the combustion stabled.

e) Allow the test chamber to stabilize. Before loading the next ignitor, clean the wire coil by removing any ash residue with a soft-bristled brush.

f) The batch of ignitors is acceptable for use when no more than one ignitor out of the 20 tested fails the specified criteria (see A.10.2). Once the batch of ignitors has been tested and certified, calculate the average peak flame temperature and average burn time, along with their standard deviations.

A.11 Waste disposal

It is presupposed that the disposal of any waste generated from manufacturing, cutting or weighing ignitors, including an entire batch that fails, is conducted in accordance with applicable hazardous-waste/environmental regulations.

A.12 Packaging and storing ignitors

A.12.1 Package the ignitors in a plastic storage container between layers of 3-mm-thick corrugated foam wrap. Place the ignitors in the grooves of the corrugated wrap. The order of placement in the storage container should be:

a) corrugated wrap with grooved side up;

b) layer of ignitors, in grooves of corrugated wrap;

c) corrugated wrap with grooved side down.

Repeat steps a) to c) until the container is full. This order of placement puts two layers of corrugated wrap between each layer of ignitors and minimizes movement when the box is moved or stored. To absorb any excess moisture which can affect the performance of the ignitors, place packets of desiccant on top of the ignitors, inside the container.

A.12.2 To prevent the ignitors from absorbing moisture during an extended storage period, place the packaged ignitors in a desiccator with a colour-changing desiccant or another type of humidity indicator. The ignitors can be stored for an indefinite period of time, provided the desiccant is changed regularly and/or the humidity in the desiccator is kept below 18 %.

Annex B
(informative)

Method to determine the flammability thresholds of materials

B.1 General

This annex provides a method to determine the oxygen concentration threshold when a material exposed to a standard ignition source self-extinguishes at a given constant total pressure, temperature, convective flow, and gravity-level conditions. The method can also be used to determine other flammability limits, such as the total pressure or forced convective velocity thresholds, while maintaining other test conditions constant. The flammability thresholds can also be determined with alternate pass/fail criteria, sample configurations and/or size, ignition mode, etc. to allow correlations with test data obtained, for example, under microgravity or reduced-gravity conditions which can have limited testing time in ground experiments.

NOTE The method described provides an assessment of the flammability of aerospace materials under laboratory conditions only. Nevertheless, the results can be used as elements of a fire risk assessment which take into account all the pertinent factors for an assessment of the fire hazard in space systems. Studies on parametric effects have been initiated to better understand the applicability of the data[15].

B.2 Test criteria

This test method attempts to determine the self-extinguishment limits of materials. Individual samples are considered to self-extinguish when the burn length is less than 15,2 cm when tested in accordance with this document or ISO 14624-2. The material is considered to self-extinguish when all samples tested (at least five) pass the burn length criteria for individual samples.

B.3 Sample preparation

A minimum of 20 samples should be prepared. Preparation of samples for testing involves the following tasks:

a) receiving and visually inspecting the material;

b) preparing samples to the proper dimensions;

c) cleaning the samples;

d) inspecting the samples (samples should be prepared exclusively for use in this test).

The sample length should be at least 15,2 cm. A standard sample length as indicated by this document and ISO 14624-2 is recommended if a direct correlation with these standards is required. Otherwise, the samples should be prepared as required in this document or ISO 14624-2.

B.4 Test system

The test system should comprise the components identified in this document or ISO 14624-2.

B.5 Pre-test procedures

Before testing, all pertinent information (including sample identification, pressure, and oxygen concentration) should be recorded on the data sheet (see Annex B). The system should be visibly clean, and all measuring devices should be in current calibration. The exposed centre section of standard-sized samples should be 5,1 cm wide. Samples should not be overly stretched or tightened, which would cause lines of horizontal stress; thin films should be mounted with 1,3 cm of slack in the width to allow for shrinkage.

The igniter specified in this document or ISO 14624-2 should be placed parallel to the lower edge of the sample and centred along the plane of the front surface of the sample. The igniter should be placed (0,6 ± 0,3) cm below the lower edge of the sample. Finally, the K-10 paper should be mounted horizontally 20,3 cm and centred directly below the sample.

B.6 Test procedures

B.6.1 Determining the upward limiting oxygen index (ULOI)

Start testing at an oxygen concentration corresponding to the ULOI for similar materials. Conduct the testing in accordance with this document or ISO 14624-2; if the sample burns less than 15,2 cm, record this as an "O" response, while if the sample burns at least 15,2 cm, record it as an "X" response on the data sheet. Observe and record the material's burning behaviour such as sparks, flame jets, burning/melting/dripping of material, and if ignition of K-10 paper occurs. Video record the tests if possible.

Select the oxygen concentration to be used for the next test as follows:

a) decrease the oxygen concentration if the burning behaviour of the preceding specimen gave an "X" response;

b) increase the oxygen concentration if the burning behaviour of the preceding specimen gave an "O" response.

Repeat the test procedures using oxygen concentration changes of any convenient step size until two oxygen concentrations, in percent volume, have been found that differ by 1 % oxygen and of which one gave an "O" response and the other an "X" response. The two results at oxygen concentrations 1 % apart which gave opposite responses do not have to be from successive specimens. The ULOI is the lower oxygen concentration when the specimen fails the 15,2 cm burn length criteria ("X" response).

NOTE 1 The oxygen concentration change of 1 % has been determined to be adequate for most conditions. Using a lower oxygen concentration change can yield higher precision but can require more tests. Using a step size of 2 % yields quicker results and can be employed when lower precision is acceptable. This step size is especially suitable when higher oxygen concentration thresholds than approximately 30 % by volume are expected.

NOTE 2 The procedure outlined in Annex C can be used to determine the ULOI when a higher precision is needed. See also the ISO 4589 series for additional details.

B.6.2 Determining the maximum oxygen concentration (MOC)

From the set of data obtained, determine the highest oxygen concentration where the specimen passed the burn length criteria ("O" response) and which is 1 % below the lowest oxygen concentration where the specimen failed ("X" response). Conduct additional tests at this oxygen concentration until a total of five tests have been completed without failure. If a failure is obtained, keep lowering the oxygen concentration by 1 % by volume until five samples pass.

NOTE When lower precision is acceptable, the use of a 2 % step size results generates an MOC that represents the highest oxygen concentration at which the material passed the burn length criteria, and which is 2 % below the lowest oxygen concentration where the material failed. See 8.1, WARNING.

B.7 Recording and reporting

The following observations should be made and recorded:

a) material identification (composition, trade name, manufacturer, etc.);