ECSS-Q-70-21A
4 October 1999

Space product assurance

Flammability testing for the screening of space materials

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Published by: ESA Publications Division
ESTEC, P.O. Box 299,
2200 AG Noordwijk,
The Netherlands

ISSN: 1028-396X

Price: € 10

Printed in The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards.

Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work.

The formulation of this Standard takes into account the existing ISO 9000 family of documents.

This Standard has been prepared by editing the ESA PSS-01-721 and incorporating RKK/Energia (Moscow) test method ZZU.0336.028, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board.

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Introduction

All non-metallic materials are inherently flammable, the degree to which this is true is dependant on the chemical nature of the material itself and the environment to which the material is exposed. In the closed environment of a manned spacecraft this can lead to a potentially dangerous situation and close control is therefore required.

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Scope

This Standard defines a multi-test procedure for the determination of the flammability characteristics of non-metallic materials under a set of closely controlled conditions. The test procedure covers both individual materials and materials used in configuration. This Standard describes a series of tests to provide data for aid in the evaluation of the suitability of materials for use in a space vehicle crew compartment. The data obtained are in respect to the ease of ignition and the flame propagation characteristics of materials.

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Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this ECSS 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 publication referred to applies.

ECSS-P-001	Glossary of terms
ECSS-Q-20	Space product assurance - Quality assurance
ECSS-Q-20-09	Space product assurance - Nonconformance control system
ECSS-Q-70	Space product assurance - Materials, mechanical parts and processes
DIN 50050-1	Space product assurance: Testing of materials; burning behaviour of materials; small burning cabinet
ISO 6941:1984	Textile fabrics — Burning behaviour — Measurement of flame spread properties of vertically oriented specimens

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Terms, definitions and abbreviated terms

3.1 Terms and definitions

The following term and definition is specific to this Standard in the sense that it is complementary or additional with respect to those contained in ECSS-P-001 and ECSS-Q-70..

flammability
a measure of the ease with which a material is set on fire

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this Standard.

Abbreviation	Meaning
C_{lim}	The minimum volumetric concentration of oxygen contained in an oxygen-nitrogen mixture, in the presence of which a material can still combust after ignition from the bottom.
r.m.s.	root-mean-square

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Test procedure

4.1 Preparatory conditions

4.1.1 Hazards, health and safety precautions

Particular attention shall be given to health and safety precautions. A safety check-list is produced below.

a. Hazards to personnel, equipment and materials shall be controlled and reduced to a minimum.

b. Hazardous substances, items and operations shall be isolated from other activities.

c. Items and controls shall be so located that personnel are not exposed to hazards such as chemical burns, electric shock, cutting edges, sharp points or toxic atmospheres.

d. Suitable warning and caution notes shall be provided in operations, storage, transport, testing, assembly, maintenance and repair instructions and distinctive markings placed on hazardous items, equipment or facilities for personnel protection.

4.1.2 Preparation of samples

4.1.2.1 Configuration of samples

Sufficient specimens of the material in their minimum thickness of intended use shall be submitted for testing (for actual numbers see the individual test methods).

4.1.2.2 Cleaning

The cleaning and other treatment of the samples shall be the same as that to which the sample will be submitted before incorporation into the spacecraft. Further cleaning or treatment shall not be carried out by the test house.

4.1.2.3 Handling and storage

Contamination of the sample during handling shall be avoided by the use of, for instance, suitable protective gloves. In addition, samples shall be stored in a cleanliness-controlled area with an ambient temperature of (22 ± 3) ºC and relative humidity of (55 ± 10) %. Coated surfaces shall be shielded from contact by using polyethylene or polypropylene bags or sheets. Mechanical damage shall be

avoided in the standard way by packing the polyethylene- or polypropylene-wrapped test pieces in clean, dust- and lint-free material.

Limited-life material shall be labelled with its relative shelf-life and date of manufacture, or date of delivery if date of manufacture is not known.

4.1.2.4 Identification

Materials submitted for testing shall be accompanied by a clear description of, for instance, the name and nature of the material or processing.

4.1.3 Facilities

4.1.3.1 Cleanliness

The work area shall be clean and free of dust. Air used for ventilation shall be filtered to prevent contamination of the workpieces by moisture, oil or dust.

4.1.3.2 Environmental conditions

a. **Test process**. Preferably the same as for conditioning (see below) unless otherwise stated.

b. **Conditioning temperature**. See 4.1.2.3 above. This can be achieved either in a conditioning room, or by the use of desiccators filled with silica gel or a saturated salt solution.

NOTE A saturated salt solution of calcium nitrate gives approximately 51 % humidity at the testing temperature.

4.1.3.3 Special utilities

Oxygen and nitrogen supplies (minimum purity 99,9 %).

4.1.4 Equipment

4.1.4.1 Test equipment

Suitable test equipment fulfilling the monitoring requirements detailed in the applicable test method shall be available.

4.1.4.2 Special apparatus

As detailed in the applicable test method.

4.2 Test methods

4.2.1 Categories

Four test methods are included within this Standard. They can be divided into two different categories as indicated below:

D **Screening tests**. These are the prime tests to be performed on a material to assess its basic acceptability or otherwise with respect to flammability. They are designed to test the material under worst case test conditions, with respect to, for instance, environment, use, or thickness. Two tests form the basis for acceptance or otherwise of most non-metallic materials (tests 1 and 2) but are very different in the data generated. The choice of which test method should be used is dependant on the project concerned and shall be specified within the business agreement. Test 3 is related specifically to wire insulation materials. Materials which meet the requirements of these tests may be considered for general application, within the constraints of the test conditions used.

D **Configuration test**. Materials failing to meet the requirements of the applicable screening test shall be subject to testing in configuration. Materials which are shown to be acceptable in this manner may be accepted for restricted application, within the constraints of the test conditions used. Materials which fail this test shall be subject to a deviation request. Examples are:

S flammable adhesives where the use is to bond two non-flammable substrates together, or

S flammable conformal coatings applied thinly to a non-flammable printed circuit board.

D **Additional tests.** These tests may be proposed related to the determination of such properties as flash and fire point, or heat of combustion. These shall, however, be decided on a case by case basis.

4.2.2 Screening tests

4.2.2.1 Test 1: Upward propagation test[1)]

a. **Scope**

The purpose of this test is to determine the flammability characteristics of candidate materials supplied to a standard format when exposed to an ignition source applied at the bottom edge. This test in general is applicable to NASA payloads (e.g. Space Station, STS). If the materials are unavailable in the standard format then the test described in subclause 4.2.3 shall be followed.

b. **Preparation of specimen**

After visual inspection to verify that no cuts, abrasions or other flaws exist, the material samples shall be prepared as follows:

1. Films, fabrics, sheets and composites shall be tested in the “as received” condition. Samples shall be cut in the form of rectangles 300 mm × 64 mm minimum. Foams and high-bulk materials shall be tested in the “as applied” thickness and have the same minimum dimensions as specified above.
2. Primers, coating materials, paints and pressure-sensitive tapes shall be applied on the substrate materials intended for use, if known. The coatings shall be applied in a thickness equivalent to normal use and post-cured in accordance with prescribed manufacturing processes. If the spacecraft substrate is not available, the coatings shall be applied to 300 mm × 60 mm × 0,075 mm aluminium panels.
3. The test specimens shall be conditioned at (22 ± 3) ºC and (55 ± 10) % relative humidity for 24 hours before testing.

c. **Test conditions: pressures and atmosphere**

The test pressure and atmosphere shall be specified to represent the most hazardous atmosphere anticipated in the spacecraft.

d. **Test equipment and apparatus**

S **Chamber**. The test chamber shall have a volume sufficient to ensure complete combustion of the sample under test. It shall have therefore a minimum volume of 250 l and be suitably constructed to ensure safe operation. A window or viewing port for visual observation and recording shall be included. Internal lighting should be installed. Suitable feed-throughs shall be available for gas inlets, evacuation, venting to air, and electricity for ignition. Organic materials used in the construction of the chamber shall be of a type that contribute little or no outgassing to the chamber.

1) Based on NASA STD 6001 Test 1.

- **Pressure gauge**. Apparatus shall include a pressure gauge capable of measuring pressures to an accuracy of 10 hPa.
- **Sample holder**. Samples with sufficient rigidity or samples on substrates of sufficient rigidity and which do not retreat from a heat source by distorting or violently shrinking may be supported using a simple clamp. Other samples shall be supported in a frame which holds them taut. The sample holder shall be so constructed as to have the minimum influence on the result by conducting heat away from the sample.
- **Ignition source**. Ignition of the sample shall be accomplished by employing a regulated energy source. The ignition source shall consist of a length of AWG 20 gauge Nichrome wire which has a nominal resistivity of 2,3 Ω/m, sufficient to wind a minimum of three turns of a Solid igniter[2)] or equivalent. The nominal diameter of this igniter is 3 mm with a length of 32 mm. The flame temperature is (1100 ± 100) ºC and burns for a duration of (25 ± 5) s. The igniter shall be activated by means of a regulated DC power source. The igniter shall be positioned 6 mm from the lower edge of the sample.

e. **Propagation rate indicator**

Propagation rate shall be observed and recorded visually in combination with manually activated timing devices to determine the propagation rate between markers on a scale positioned on the sample holder. Timing shall be started at the first visual indication of combustion and stopped when the flame ceases to propagate upwards. Where appropriate it is also acceptable to record the total burn time and remove the sample to measure the total burn length either directly or by subtraction. In this case care shall be taken to avoid overestimating the burn length by measuring soot deposits higher up the sample.

f. **Pre-test procedure**

Before each series of tests the equipment shall be calibrated in the following manner:

1. Set the pressure regulators on the oxygen and nitrogen lines (0,17 - 0,21) MPa. Close the valve for the oxygen inlet to the equipment and open the nitrogen valve. Adjust the flow to give a rate of 100 ml/min through the analyser. The meter reading with only nitrogen flowing should be 0 %. Adjust the calibration zero until this value is obtained.
2. Repeat the procedure, but with the nitrogen flow off and only oxygen passing through the equipment. The meter should now read 100 %. If this is not the case, then adjust the calibration control to bring it to 100 %.
3. Repeat steps 1. and 2. if necessary.

Instead of the method referred to above, bottles of calibrated gases having the worst-case atmosphere may be used.

g. **Test procedure**

1. Adjust nitrogen and oxygen needle valves to produce the test atmosphere (step f.).
2. Place the sample in position in the chamber.
3. Place igniter in coil of Nichrome wire and place between electrodes in the chamber.
4. Evacuate chamber to below 1400 Pa.
5. Fill chamber with test atmosphere.
6. Allow the sample to soak in the test gas mixture for a period of at least three minutes.

2) A suitable source of igniters is available from NASA White Sands test facility. In addition a method for the preparation of suitable igniters is included in annex A.

7. Start video recording.
8. Apply current to the igniter until it ignites and then immediately stop the current.
9. Record whether the sample is non-combustible or self-extinguishing or burning.
10. Note combustion characteristics (e.g. nature and colour of flame, amount of smoke, burning drops, sputtering, glowing combustion).
11. Record the maximum pressure reached in the chamber.

h. **Acceptance criteria**

Materials shall be considered non-combustible, or self-extinguishing if the combustion zone propagates less than 150 mm into the sample with minimum-use thickness and the time of burning does not exceed 10 minutes. There shall be no sparking, sputtering, or dripping of flaming particles from the test sample. A minimum of three samples shall be tested. Failure of any of the three constitutes failure of the material.

i. **Test results**

The following properties shall be recorded:

- Complete description of sample tested, including trade name, manufacturer, chemical nature, dimensions, test atmosphere and processing details.
- Time, length and rate of burning. Observations concerning the nature of the flame noted in step g. and percentage oxygen remaining at the end of test. If the oxygen concentration shows a value lower by 20 % of the original test atmosphere a re-test shall be required in a larger test chamber.

4.2.2.2 Test 2: Standard test method for the determination of the oxygen concentration limit during the combustion of polymer materials[3)]

a. **Scope**

This procedure shall be used to determine the concentration limit of oxygen (C_{lim}) during the combustion of candidate materials. The applicability of this test shall be specified in the business agreement.

- The oxygen concentration limit during the combustion of polymeric materials is defined as the minimum volumetric amount of oxygen contained in the nitrogen-oxygen mixture, in the presence of which the material can still combust after ignition from the bottom.
- The oxygen concentration limit shall provide a comparative evaluation of the tendency of polymeric materials to burn and to assess the fire resistance of these materials.
- The oxygen concentration limit during the combustion of polymer materials should be considered as one of the main indices characterizing the risk of fire which materials present before being considered for use in environments containing various oxygen levels.

b. **Description of the equipment**

The oxygen concentration limit, during the combustion of polymer materials, is determined using equipment of which a sketch is shown in Figure 1. This equipment shall comprise:

3) Based on RKK Energia test method ZZU.0336.028.

- A test column mounted vertically (no. 1 in Figure 1) made of quartz glass with an inside diameter of 75 mm and a height of 370 mm. Under the column a quartz tube is placed with an inside diameter of 75 mm and a height of 70 mm, filled with a layer of glass balls 3 mm to 5 mm in diameter, which are used to distribute the gaseous mixture evenly over the section of the tube (no. 5 in Figure 1).
- A sample holder (no. 2 in Figure 1) clamping the sample from the top in a vertical position at the centre of the quartz tube. A frame (Figure 2) is used to grip fabric, foils or film samples.
- A gas burner (no. 4 in Figure 1), a tube made of copper with an inside diameter of 2,5 mm, placed along the axis of the quartz column and through the glass balls layer. The flame temperature is 850 °C; the height of the flame is 25 mm; the pressure is (17 ± 2) kPa.
- A spark igniter consisting of two insulated electrodes is located on both sides of the gas burner tube (no. 7 in Figure 1).
- An analyser module comprising a mixing chamber and an oxygen gas analyser is installed in the oxygen-nitrogen mix line (no. 10 in Figure 1). Range: (0 - 25) % and (0 - 100) %; Accuracy: ± 0,1 %, with a paramagnetic detector.
- A pressure reducing valve, a flowmeter and an on-off valve are installed in the fuel gas line (no. 9 in Figure 1).
- A chronometer.

The tests are carried out with a suitable exhaust connected.

c. **Samples**

The following points are relevant in addition to those identified in step b.

- Conditions relative to the production of samples from thermosetting polymer materials not melting when burning:
  - The materials shall be in the form of a small bar with a section of (4 ± 1) mm × (10 ± 1) mm and a length of (200± 5) mm.
  - For the tests on woven and film materials, natural and artificial leather the samples are required in their thickness, (50 ± 1) mm wide and (200 ± 5) mm long. These samples shall be used fixed in a metal frame (see Figure 4).
  - For tests carried out on fibres which do not deform and do not melt when burnt, samples are produced from these fibres in the form of braids (200 ± 5) mm long and with a linear density equal to (5 ± 0,3) g/m (mass (1 ± 0,3) g).
- Conditions relative to the production of samples from thermoplastic polymer materials which melt when burning:
  - Samples in the form of a small bar with a section of (4 ± 1) mm × (10 ± 1) mm and a length of (200 ± 5) mm are surrounded with glass fibres into a lattice work (see Figure 5).
  - To produce samples from film materials which melt take a sheet one side of which is equal to 200 mm (length of the sample) with a mass equal to (8 ± 1) g. Roll the sheet into a compact roll, and surround with glass fibre to form a bar. The mass of the glass fibres shall not exceed 1,6 g (20 % of the mass of the sample).
- Tests of coatings deposited on metallic surfaces (undercoat, paint, enamel, varnish) shall be carried out on samples in configuration simulating a portion of actual equipment and shall be supported in the sample holder shown in Figure 3.

d. **Preparation of the test equipment**

1. Choose the regulating flow for nitrogen and oxygen so that by regulating the pressure reducing valves the composition specified for the gaseous mixture can be obtained. Check the composition of the gaseous mixture using the gas analyser.
2. Enter into the test column (no. 1 in Figure 1) a mixture of oxygen and nitrogen as per that specified, the flow monitored on the flowmeter being equal to (442 ± 44) cm^3/s which enables an average volumetric speed of flow of the mixture of (10 ± 1) cm/s to be obtained in the tube (no. 1 in Figure 1). Monitor the level of the oxygen content in the gaseous mixture by means of the automatic gas analyser.
3. Light the gas burner and regulate the flow of combustible gas to 0,03-0,05 l/min using the flowmeter.
4. After having checked that the gas burner (no. 4 in Figure 1) is functioning properly, cut off the supply of combustible gas to the burner followed by that of the nitrogen-oxygen mix.

e. **Test procedure**

- Tests shall be carried out at normal room temperature.
- The material sample shall be fixed in the relevant sample holder and placed in the test column in the vertical position so that the bottom edge of the sample is 10 mm from the burner, and such that the vertical axis of the sample coincides with the axis of the gas burner.
- Enter the gaseous mixture into the system for at least 30 s.
- Ignite the gas burner and adjust the flow of combustible gas to 0,03-0,05 l/min, using the flowmeter.
- Once the sample has started to burn at a stable rate, but at the latest 60 s after the ignitor flame has caused ignition of the sample, cut off the supply of combustible gas to the burner; measure the duration of combustion. While the sample burns maintain the composition and flow of the gaseous mixture constant using the mixer.
- If the sample burns over its whole length or if combustion lasts for at least 120 s, the test shall be repeated with a lower concentration of oxygen.
- When the anticipated value of the oxygen concentration limit is not known in advance, the first test shall be carried out using only air. If the sample does not burn in air, a second test shall be started with an oxygen concentration of 30 % to 35 %.
- A new sample of material shall be used for each test.
- In the subsequent tests the oxygen concentration of the gaseous atmosphere shall be varied until the difference of the concentrations at which the sample burns or extinguishes is within 1 %.

f. **Results**

- The oxygen concentration limit (C_{lim}) is expressed as a percentage and determined using the equation:

$$C_{\mathrm{lim}} = \frac{\sum_{i=1}^{n} C_{\mathrm{lim},i}}{n}$$

i.e. the arithmetic average of the concentration limit calculated as a function of the results of unit measurements of ($C_{\mathrm{lim},i}$).

At least five samples shall be used.

S The results of the tests shall be entered in a report. This report shall contain:

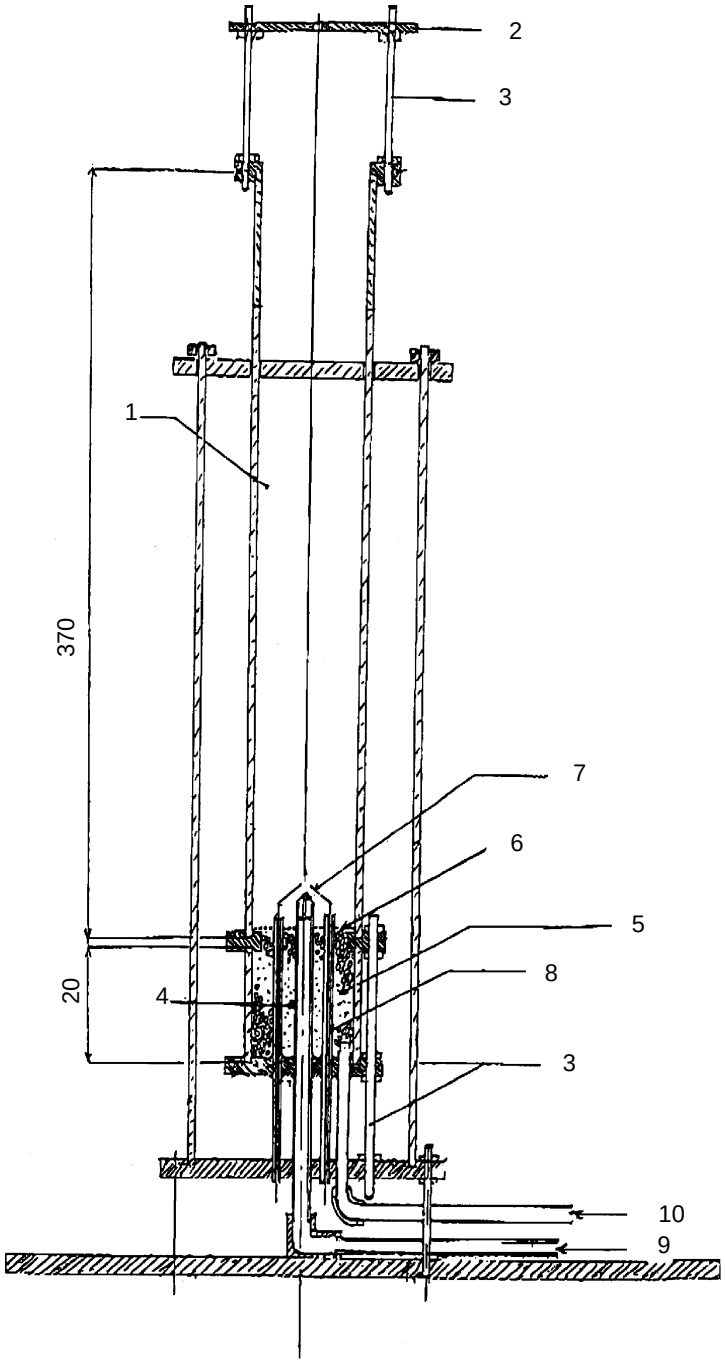
— the trade name and chemical nature of the material, the production date of the material, if known;

— the name of the manufacturer;

— a brief description of the nature of the sample (e.g. size, thickness.);

— the oxygen concentration limits for each test taken separately and their average value;

— the date on which the tests were carried out.



1. Test column
2. Sample holder
3. Threaded shaft ∅ 4 mm
4. Gas burner
5. Diffuser
6. Inox grid mesh 1 mm
7. Spark igniter
8. Insulating ceramic
9. Fuel gas line
10. O_2 + N_2 mix line

Figure 1: Diagram of the equipment used to determine the oxygen concentration limit

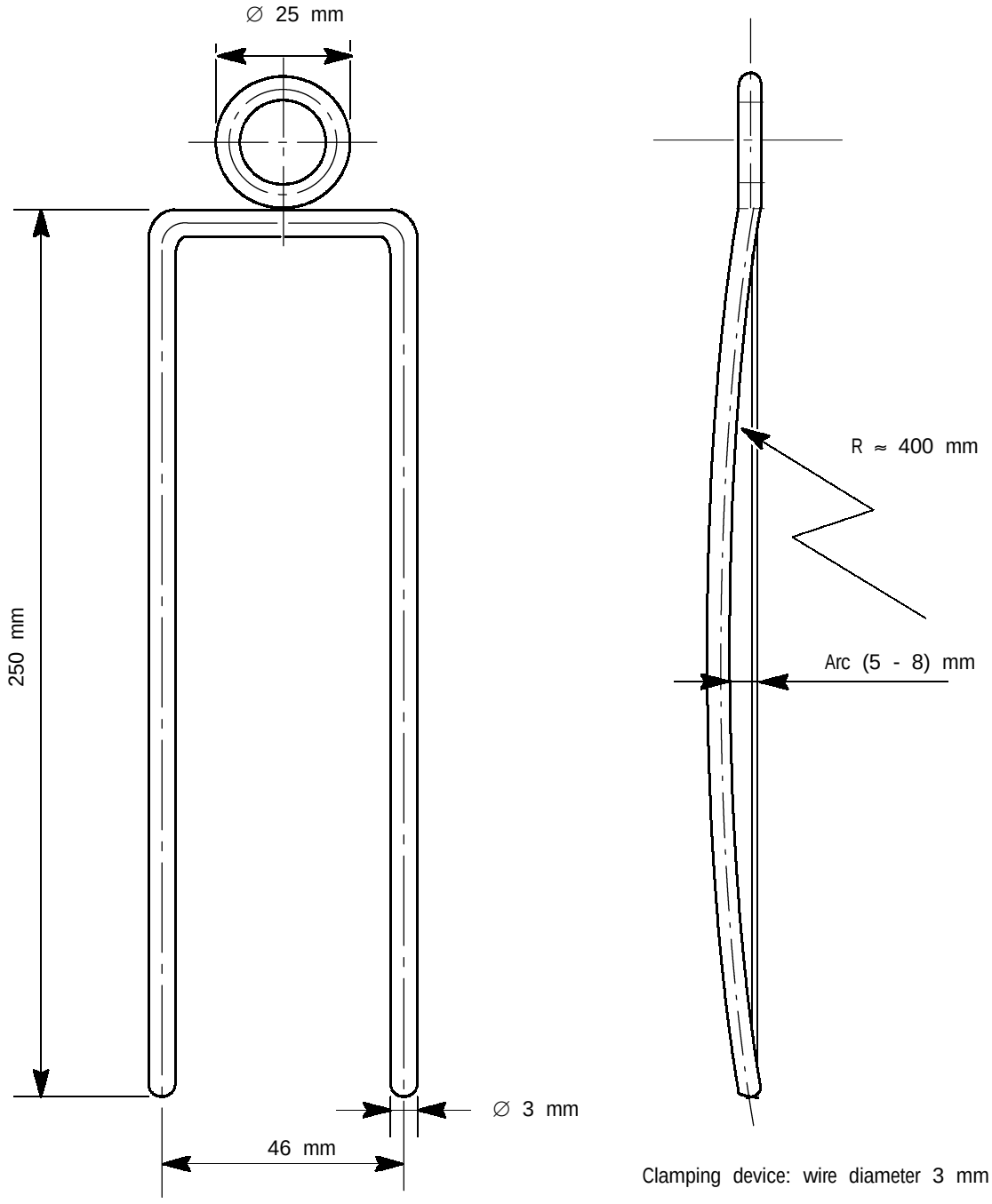


Figure 2: Frame used to fix the sample

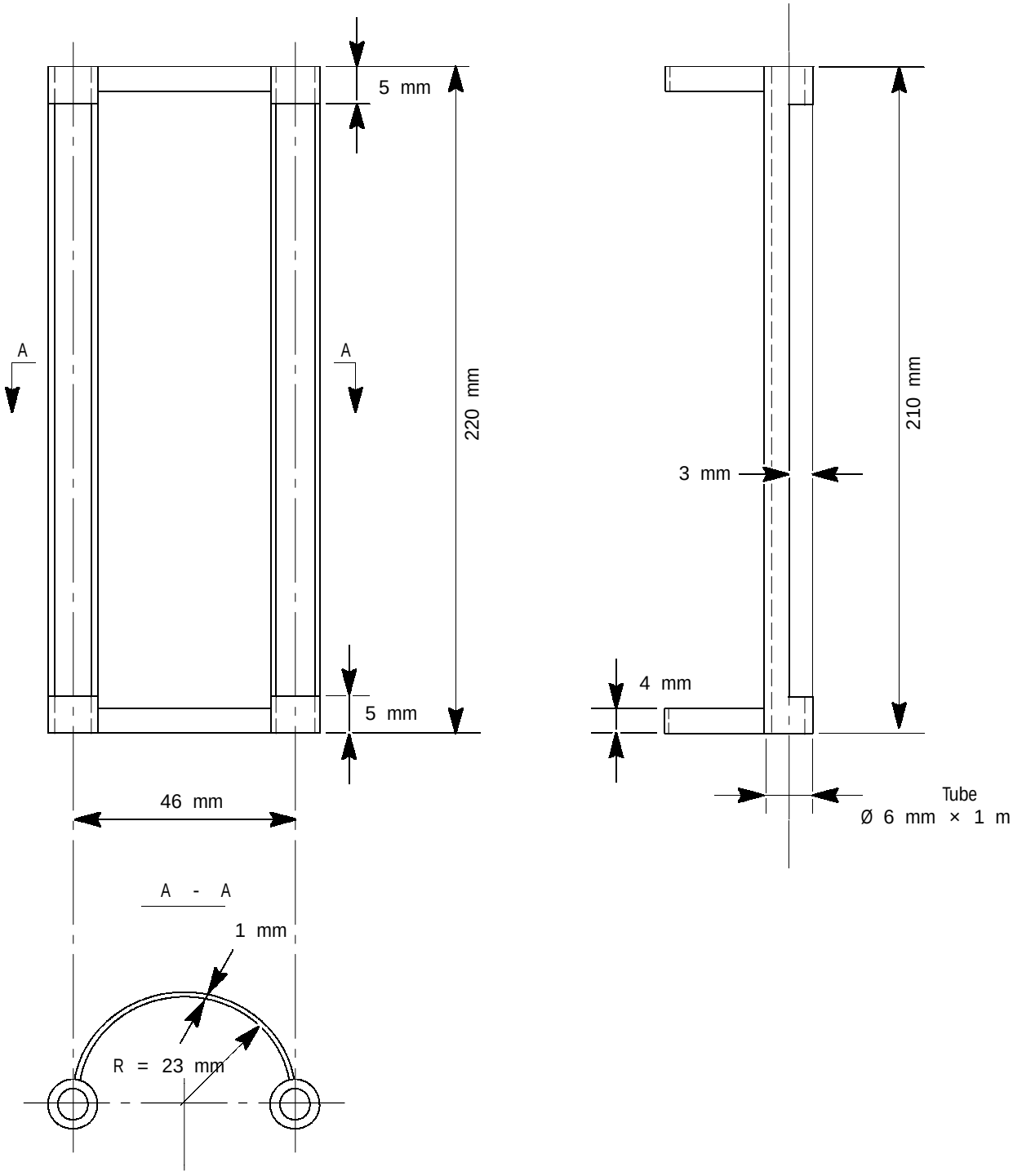


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Figure 3: Sample holder

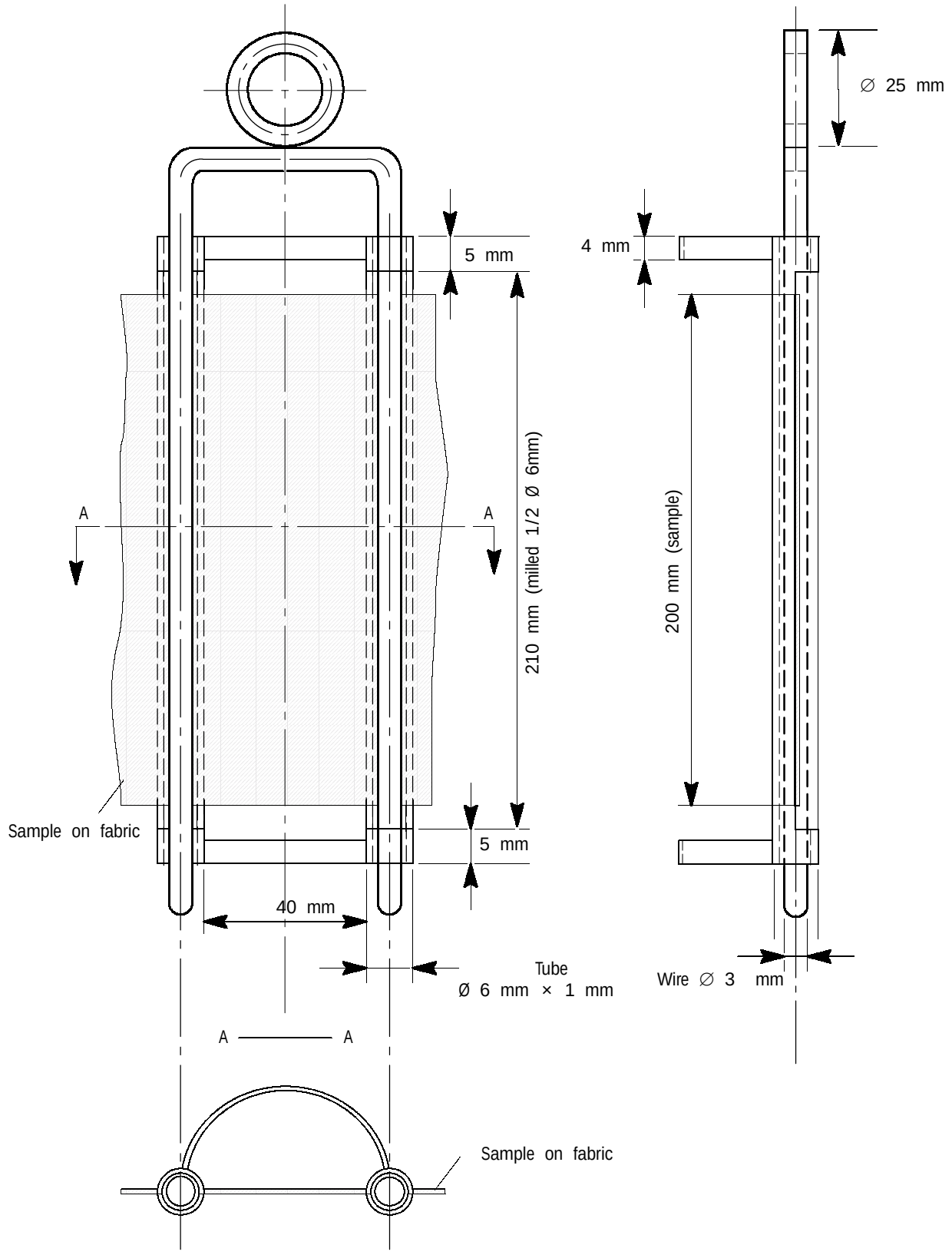

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Figure 4: Sample holder

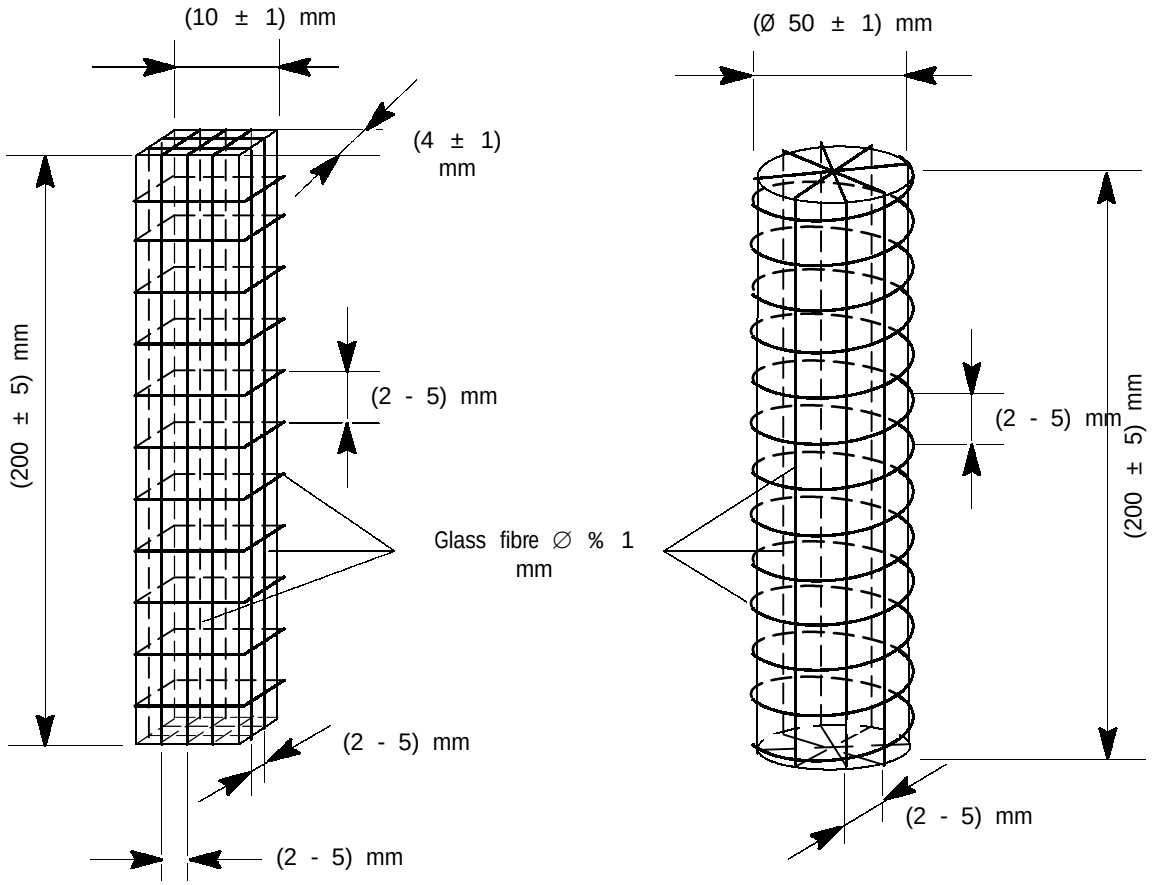

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Figure 5: Samples from thermoplastic polymer materials

4.2.2.3 Test 3: Electrical wire insulation flammability test method

a. **Scope**

This test is designed to screen wire insulation for flammability characteristics. The test is limited to gauges AWG 20 to AWG 10 with copper conductors and is limited to normal pressures with a maximum oxygen concentration of volume fraction 25 %.

b. **Preparation of specimens**

Insulated wire samples shall be free of cuts, abrasions and other flaws as determined by close visual inspection. Samples shall also be accompanied by full material identification as outlined in subclause 4.1.2.4. Five specimens, each a metre in length, shall be cut consecutively from the same coil of wire and shall be cleaned of foreign matter and residue, using a method compatible with the insulation being tested. The specimens shall be conditioned prior to testing, at (55 ± 10) % relative humidity and at a temperature of (22 ± 3) ºC for a period of at least 16 hours.

Remove approximately 25 mm of the insulation from both ends of the test specimen, measure and record the conductor resistance and ambient temperature, and position in the test chamber following the test procedure set out in subclause f.

c. **Test conditions: pressure and atmosphere**

The test pressure and atmosphere shall be designated by the project office and shall represent the most hazardous atmosphere anticipated in the spacecraft within the confines of the scope of this test (see subclause a.).

d. **Test equipment and apparatus**

- **Chamber**. The test chamber shall have a volume of at least 250 l and shall conform to DIN 50050 with the height modified according to ISO 6941: 1984 (see Figure 6). Further modifications shall include feed-throughs for the supply of the test atmosphere, an arrangement for the diffusion of the test atmosphere to eliminate high flows, feed-throughs for air and fuel gas for the burner, electricity for the sample and an arrangement for mounting the sample under slight tension at 75° to the horizontal.
- **Electrical supply**. The external electrical supply shall be capable of providing a large steady DC current up to 100 A and shall include accurate voltage and current meters capable of measuring the voltage drop across the wire and the current flowing through it to two decimal places.
- **Resistance meter**. A resistance meter capable of measuring resistances under 100 Ω to an accuracy of 0,01 Ω shall be available.
- **Burner**. The burner shall be of a Bunsen or Tirrill type, with a 9,5 mm bore modified to supply an external supply of air to the burner collar (Figure 7).
- **Flame temperature**. The flame temperature shall be (1100 ± 100) ºC measured at a point 35 mm from the end of the burner barrel. This can be achieved with commercial grade fuel gas (minimum 85 % purity) and forced air to produce a flame 75 mm high with an inner blue cone of 25 mm.
- **Burner mounting**. The burner shall be mounted perpendicular and at 30º to the vertical plane of the specimen as shown in Figure 8.
- **Wire tension**. The specimen shall be kept taut by suspension of a weight as shown in Figure 8. The value of the weight shall be such that no undue strain is placed on the wire and can be adjusted to accommodate samples of different size and stiffness.
- **Visual record**. Visual records shall be made and retained of all flammability tests. A timer shall be so positioned that it is visible to the camera.

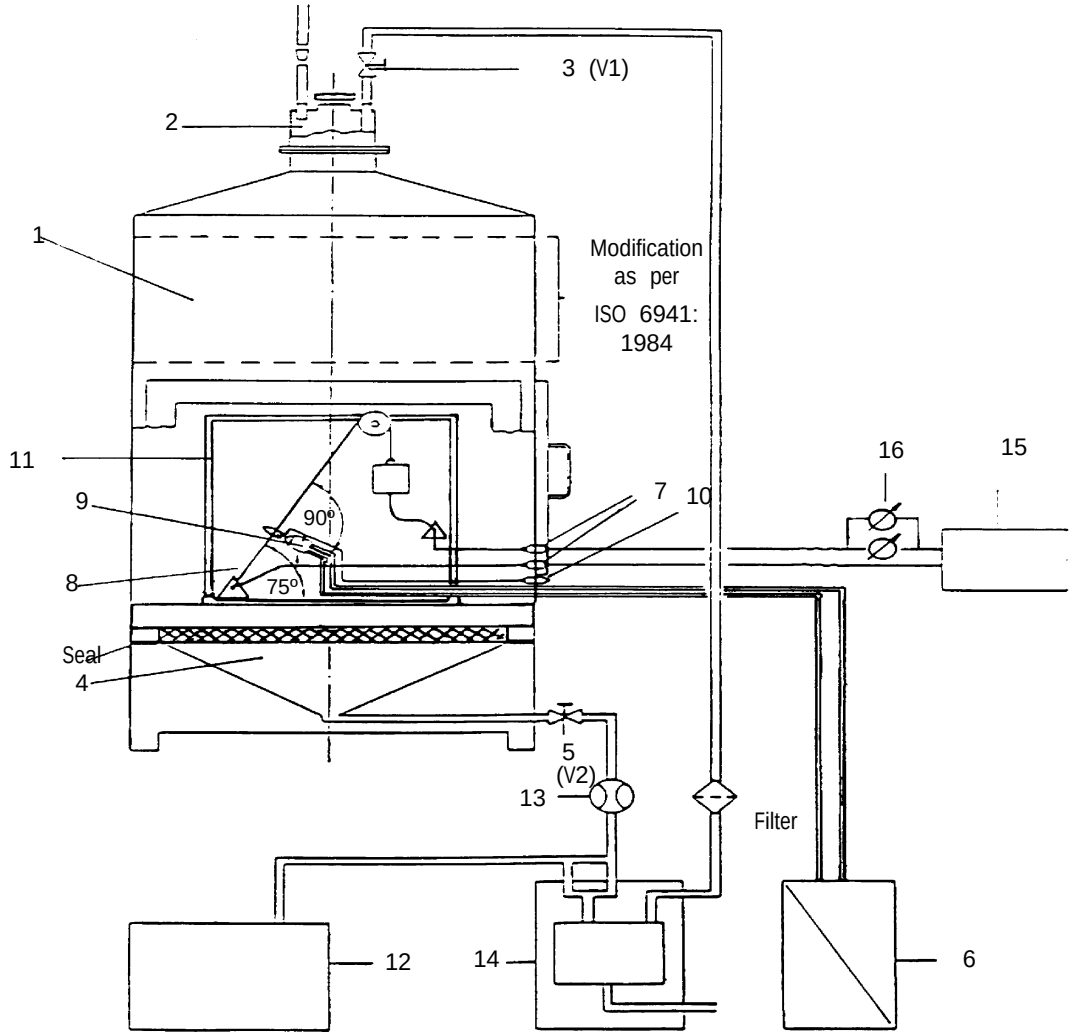

Figure 6: Test set up for flammability of electric wires under heated wire conditions at 25 % by volume oxygen

Table 1: Description of test equipment (as per Figure 6)

Item no.	Description	Remarks
1	Test chamber	DIN 50050 part 1, modified as per Figure 5 Volume of chamber = 250 l
2	Upper adapter	D To open/close outlet of item 1 D Equipped with two outlets: S for sampling of gases S for measurement of oxygen measurement
3	Shut-off valve V1	To open/close the line for oxygen measurement
4	Distribution unit	For distribution of test atmosphere

Table 1: Description of test equipment (as per Figure 6) *(continued)*

Item no.	Description	Remarks
5	Shut-off valve V2	To open/close the atmosphere inlet
6	Burner supply inlet	Fuel gas/air supply for burner
7	Feed-through	For electrical current load of test sample
8	Sample and burner assembly	60º test Burner 90º relative to wire 30º relative to vertical plane of specimen
9	Burner	Bunsen/Tirrill burner type as Figure 7 Length of flame: 75 mm Length of cone: 25 mm Temperature: (1100 ± 100) ºC Measured: 35 mm above burner External gas/air: fuel gas/air
10	Igniter	Electrical, of the continuous spark type
11	Support structure	Used for example: D sample holder D burner D igniter D electrical connectors Design as Figure 8 The support structure does not influence the test atmosphere distribution
12	Test atmosphere supply	Gas mixture of nitrogen and oxygen ((25 ± 0,2) % volume fraction of oxygen) at ambient conditions Option 1: supply of pre-mixed gases Option 2: unit for mixing gases from separate bottles and measuring oxygen concentration (see item 14)
13	Flowmeter	Capable of measuring 2 l/min to 25 l/min
14	Oxygen measuring unit	(Optional)
15	Electrical power source	Capable of providing a large steady DC current (e.g. 0-100 A) sufficient to raise the conductor temperature to the desired level
16	Measurement of wire temperature	Instrument to measure: D conductor resistance (4-terminal DC resistance bridge measuring mΩ to an accuracy of 0,01 mΩ. D voltage accurate to 1 mV D current to an accuracy of 10mA

e. **Pre-test procedure**

1. Place, temporarily, the sample in position and adjust the position of the burner relative to the sample.

   NOTE It is helpful to make a measuring piece which can be fitted into the barrel of the burner and which then extends the

length of the burner by 35 mm. This then contacts the sample when the burner is at the correct stand-off distance.

2. Remove the sample, close the chamber door, open the chamber vent and switch the extractor fan on.
3. Making sure the DC power is off, switch on the electrical supply and the measuring instruments.
4. Close needle valves to fuel gas and air flowmeters.
5. Switch on main valves and using needle valve adjust the fuel gas flow to approximately 0,35 l/min.
6. Switch off main valve and allow the chamber to vent for five minutes.
7. Switch on main valve and ignite burner. Adjust air flow to approximately 6 l/min. Check flame height and temperature and adjust gas flows if necessary.
8. Check that the burner can be switched on and off repeatedly.
9. Switch off the burner, close the chamber vent and switch off extraction fan.
10. Switch on supply valves for nitrogen and oxygen. Adjust the rate of flow to 25 l/min and the concentration of oxygen to the test atmosphere concentration.
11. Switch off gas supplies. The equipment is now ready for use.

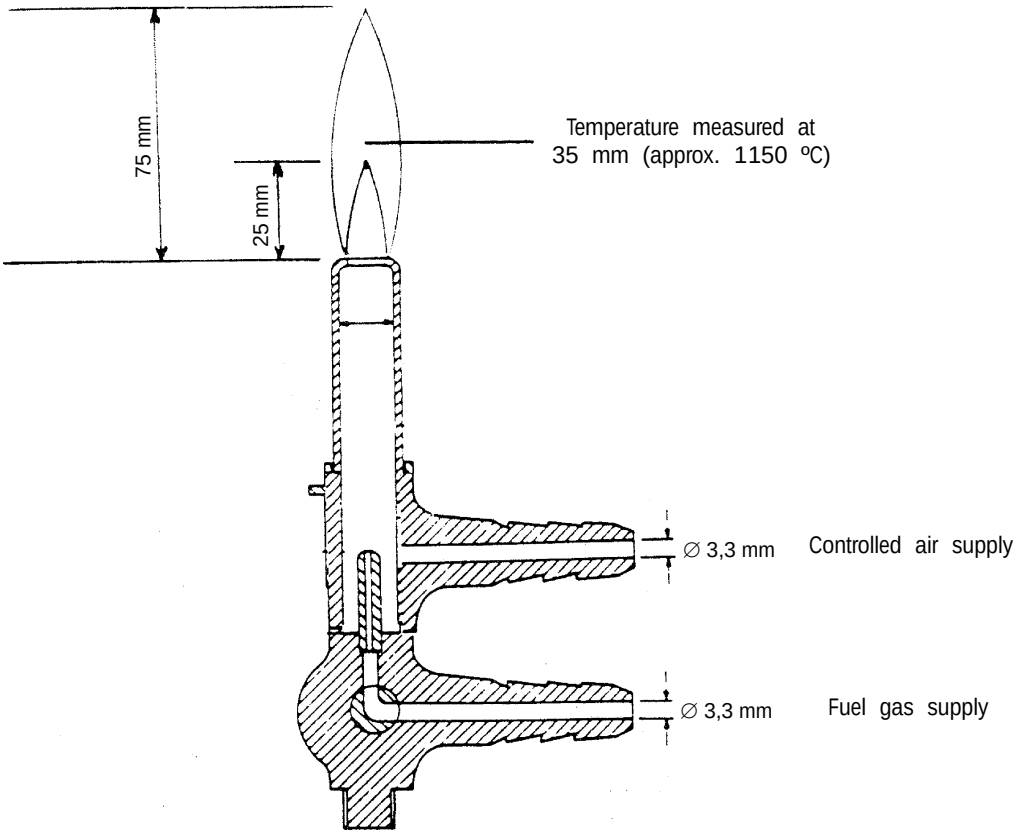

Figure 7: General arrangement of modified burner and flame dimensions

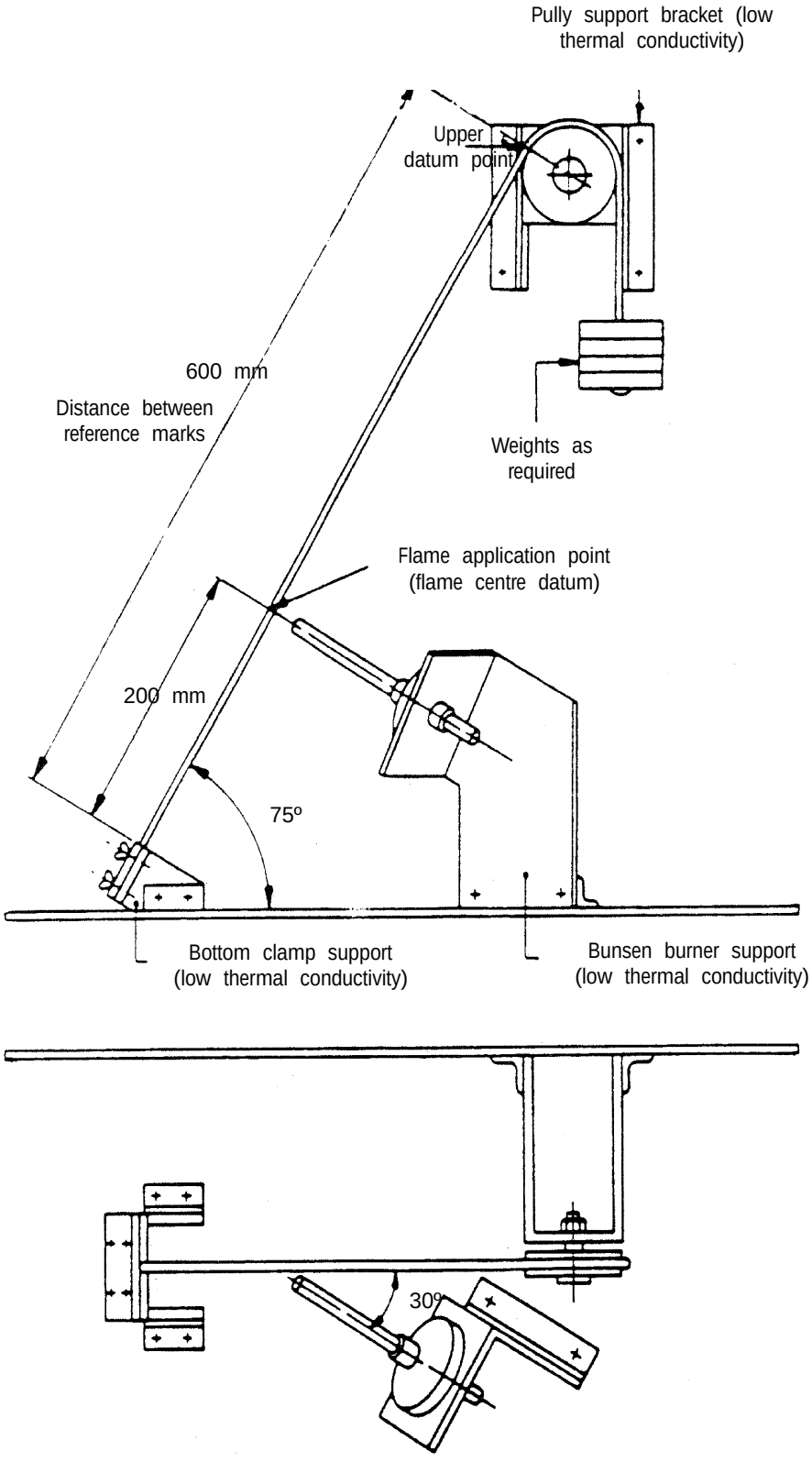

Figure 8: General arrangement of apparatus for flammability test

f. **Test procedure**

1. **Sample positioning**. Position one of the prepared samples in the test chamber as shown in Figure 8. The conductor is clamped at the lower bottom left-hand side of the apparatus by means of the electrical connector block. The wire is then passed under the lower left-hand guide and over the upper right-hand guide pulley where a weight is attached to keep the sample taut. The other end is then connected electrically to complete the circuit.
2. **Test atmosphere**. Open the vent and switch on the extractor fan. Open the oxygen and nitrogen supply valves and allow the chamber to fill by purging the chamber at a flow rate of 25 l/min for ten minutes. Reduce the flow to 2,5 l/min and maintain this flow throughout the preheating, ignition and combustion of the specimen.
3. **Pre-heating of conductor**. Apply a DC electric current (I) to the conductor and measure the voltage drop (V). From the current and voltage values calculate the resistance of the conductor at elevated temperature (R_T).

$$R_T = \frac{V}{I}$$

The temperature (T ºC) of the conductor is determined from the change in resistance using the following formula based on the variation of the specific resistivity of copper with temperature.

$$R_T = \left\{\frac{(T - 20)}{250} + 1\right\} \times R_{20}$$

Where R_{20} is the resistance measured earlier at ambient temperature (20 ºC). Adjust the current so that the conductor temperature stabilizes at the maximum operating temperature for the wire taken from the manufacturer's specification.

Maintain this temperature (± 3 %) for five minutes before igniting the flame. No further alteration shall be made to the current until the test is completed.

4. **Flame application.** Apply the flame to the specimen for a period of 15 s and then immediately extinguish the burner.
5. **Termination of test.** After all flaming has ceased, note the time, continue to apply current for a further 60 s and observe. If no further flaming occurs, switch off the current, close the oxygen supply valve and vent the chamber.
6. If the sample breaks the test shall be considered null and void.

g. **Acceptance criteria**

Prior to flame application there shall be no spontaneous combustion, splitting of the insulation or baring of the conductor. During ignition and combustion there shall be no flaming droplets or particles. After the burner is extinguished the wire shall cease flaming within ten seconds and within a total burn length of 150 mm, measured from the downward extent of propagation to the upward extent of propagation and including damage caused by the burner itself.

h. **Test results**

Test result reports shall include the following:

- Complete description of sample tested including type, manufacturer and maximum specified temperature.
- Results of each test including time of any afterburn, burnt length and observations such as flaming particles.
- Oxygen concentration, flame application time, initial conductor resistance, final current value and final conductor temperature.

4.2.3 Test 4: Configuration test method

a. **Scope**

This test is designed to determine the flammability characteristics of materials configured in the same manner as that in qualification and subsequent spacecraft models. It is intended to determine whether a flammability hazard exists when a material, which fails the basic screening test, is desired to be used.

b. **Test sample configuration**

- The sample to be tested shall be fully representative of the configuration in which the materials proposed are to be used.
- The unit shall contain materials configured and processed in the “as to be used” state. Metallic materials shall be representative of the alloy to be used. Expensive components may be simulated, but the basic material, geometry and mass of the components shall be in the “as to be used” state. An example of simulation is the use of failed or sub-standard electronic components instead of usable ones.

c. **Test pressure and atmosphere**

As defined by the system requirements.

d. **Test equipment and apparatus**

As given in subclause 4.2.2.1 d.

Ignition shall be either by electrical overload (simulating worst-case conditions) or by open flame.

e. **Pre-test procedure**

Follow the pretest procedure detailed in subclause 4.2.2.1 f. with the following additions:

- Before the test a fire hazard analysis shall be performed that clearly defines the critical items per area and the placement of the igniter or the wiring which may be subject to electrical overload. In this latter case current/voltage levels shall be defined which are representative of the anticipated worst case failure conditions.
- The sample shall be photographed showing the positioning of the igniter before and after each test.

f. **Test procedure**

Follow the test procedure for the upward propagation test, subclause 4.2.2.1 g., or apply a suitable electrical current to the defined wiring, such that ignition will occur.

g. **Acceptance criteria**

The results of the test should demonstrate that there cannot be a propagation of flame to adjacent materials and no sputtering, dripping or release of hot or burning particles. Where this can be so demonstrated the material may be considered acceptable for use in the configuration as tested.

h. **Test results**

The following properties shall be recorded:

- identification and dimension of the assembly tested;
- identification by generic name of all materials tested in the configuration sample;
- manufacturer's designation for all the materials;
- weight and surface area of the nonmetallic materials;
- combustion characteristics;
- flame propagation paths within the assembly;
- percentage oxygen remaining at the end of test;
- evaluation of the effects of the fire on the configuration sample and whether or not the material is considered acceptable for restricted application.

5

Quality assurance

5.1 General

The quality assurance requirements of ECSS-Q-20 are applicable.

5.2 Data

The quality records (e.g. logbooks) shall be retained for at least ten years or in accordance with project contract requirements, and contain as a minimum the following:

a. copy of final inspection documentation;

b. nonconformance reports and corrective actions (if applicable);

c. copy of the inspection and test with reference to the relevant procedure.

5.3 Nonconformance

Any nonconformance which is observed in respect of the test shall be dispositioned in accordance with the quality assurance requirements, see ECSS-Q-20-09.

5.4 Calibration

Each reference standard and piece of measuring equipment shall be calibrated. Any suspected or actual equipment failure shall be recorded as a project nonconformance report so that previous results may be examined to ascertain whether or not re-inspection and retesting is required. The customer shall be notified of the nonconformance details.

5.5 Traceability

Traceability shall be maintained throughout each test from incoming inspection to final test, including details of test equipment and personnel employed in performing the task.

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Annex A (informative)

Preparation and qualification of chemical igniters [4)]

A.1 General

This annex provides a standard procedure for preparing, certifying and storing the chemical igniters used in this Standard.

A.2 Safety requirements

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

A.3 Materials and equipment

A.3.1 Hexamethylenetetramine (HMT)

The HMT shall be received as a 98 % pure reagent grade compound in powder form. It shall be packaged and stored properly to prevent moisture contamination.

A.3.2 Anhydrous sodium metasilicate

The sodium metasilicate shall be received as a 98 % pure reagent grade compound in granule form. It shall be packaged and stored properly to prevent moisture contamination.

A.3.3 Gum arabic (acacia)

The gum arabic shall be received in powder form.

A.3.4 Hammer mill

The hammer mill is for grinding the dry components of the igniter mixture.

A.3.5 Glove box with a temperature/humidity meter

The glove box is used in the grinding of some portions of the dry ingredients.

A.3.6 Bags

The bags are for storage of the ground dry ingredients.

4) From ISO/CD 14624-1 (Commonly prepared by ISO TC20/SC14 and ECSS).

A.3.7 040 mesh screen

The 040 mesh screen is used for sieving the ground dry ingredients.

A.3.8 Fume hood

The fume hood is used in the grinding of some portions of the dry ingredients, and for mixing the igniter dough. The air velocity of the fume hood shall be in excess of 30 linear m/s.

A.3.9 Respirator with organic canisters

The respirator is required for the grinding of the HMT.

A.3.10 Deionized water

The deionized water is for mixing with the dry ingredients to form the igniter dough.

A.3.11 250 ml burette

The burette is for holding, and gradually adding, the deionized water to the mixture.

A.3.12 Heavy duty electric mixer

The mixer is for mixing the igniter dough.

A.3.13 Spatula

The spatula is for scraping the sides of the mixing bowl during preparation of the igniter dough.

A.3.14 Plastic trays

These non-stick trays, approximately 7,6 cm × 38 cm × 0,15 cm, are used to catch the extruded igniter dough, and hold it while it dries.

A.3.15 Conveyor belt

The conveyor belt is used to move the plastic trays at a constant rate, so that the string of igniter dough is not stretched or allowed to become too thick.

A.3.16 Extruder

The extruder is used for extruding the igniter dough onto the plastic trays.

A.3.17 Cutting tools

The cutting tools are used for cutting the igniters to proper lengths.

A.3.18 Drying racks

The drying racks are for holding the plastic trays containing the igniter dough string.

A.3.19 Desiccator and desiccant

These are used to ensure the proper humidity is maintained during drying and storage of the igniters.

A.3.20 Scale

The scale is used for weighing the dried igniters.

A.3.21 Plastic corrugated holder

The holder is used when cutting overweight dried igniters to a length that ensures proper weight.

A.3.22 Certified breating air

The breathing air is used in the certification of the igniters.

A.3.23 Voltage source

The voltage source shall be capable of providing 15 A (r.m.s.). It is used in the certification of the igniters.

A.3.24 90 mm, bare nickel chromium wire

The wire shall have a nominal resistivity of 2,3 Ω/m. It is used in the certification of the igniters.

A.3.25 Calibrated ruler

The ruler is used for measuring the length of the igniters, and the igniter flame height during certification.

A.3.26 Test chamber

The test chamber (or fume hood) is used during certification of the igniters.

A.3.27 Calibrated stop watch

The stop watch is used to determine burn time during certification of the igniters.

A.3.28 Soft bristled brush

The brush is used to clean the igniter coil between certification of individual igniters.

A.3.29 Plastic container (box)

The plastic container is used for storage of the igniters.

A.3.30 Foam corrugated wrap

The corrugated wrap is used for storage of the igniters.

A.4 Grinding the igniter mix

a. To achieve a homogeneous mixture, the raw materials shall be ground using a hammer mill. Grinding is not necessary for the gum arabic.

b. Sodium metasilicate shall be ground in a glove box. Place the hammer mill, the material to be ground and 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 040 mesh screen inside the hammer mill. Seal the glove box and before grinding the material, purge the glove box with dry air for approximately four hours or until the humidity inside the glove box is below 10 %.

c. Grind the material. Detach the bag from the hammer mill, seal the bag, and place the bag inside another bag (see f.).

d. Clean the hammer mill between the grinding of different materials.

e. The HMT shall be ground in a fume hood. The required air velocity of the fume hood shall be in excess of 30 m/s (linear), and a respirator with organic canisters shall be worn by the operator. Follow the same procedures as when grinding the sodium metasilicate (step b.).

f. After grinding, store each material separately. Double bag the material and seal each bag. Identify the ground material and store.

A.5 Weighing the igniter mix

a. To make a 400 g mixture, mix the following amounts of each solid ingredient:

(280,8 ± 0,2) g HMT,

(105,2 ± 0,2) g sodium metasilicate, anhydrous,

(14,0 ± 0,2) g gum arabic,

b. For other size batches, the mixture shall be comprised of (70,2 ± 0,1) % HMT, (26,3 ± 0,1) % sodium metasilicate, anhydrous, and (3,5 ± 0,1) % gum arabic.

c. On the day of extrusion, weigh the appropriate amount of each material, and mix thoroughly. Do not mix the dry ingredients prior to the day of extrusion.

A.6 Adding water

a. Pour 200 ml of room temperature deionized water into a 250 ml burette.

b. Open the burette and pour approximately 10 ml of deionized water into the mixing bowl of a heavy duty electric mixer.

c. Place the dry igniter mix into the mixing bowl. Ensure the igniter mix is evenly distributed in the mixing bowl.

d. Turn the electric mixer to low speed, and slowly add the deionized water to the mixture. Initially, the mixture will be very wet. As the sodium metasilicate absorbs the water, the mix will start to thicken, and eventually achieve a dough-like consistency. This could take 20-30 min depending on environmental conditions. During mixing, the sides of the mixing bowl shall to be scraped with a spatula.

e. As the proper dough-like consistency is achieved, the mix will start to pull away from the sides of the bowl. When this occurs, stop adding water. Too much water will cause the mixture to be too wet to extrude. Generally, 190-200 ml of the deionized water in the burette shall be added to the mixture.

A.7 Extruding the igniters

a. Extruding the igniters is a three person operation. One person shall place the plastic trays onto the conveyor belt. One person shall control the process by adjusting the conveyor belt speed, extruder controller speed, and by cutting the extruded igniter dough between trays. The final person shall remove the trays from the conveyor belt and place them in drying racks.

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

c. Assemble the extruder and fill with igniter dough.

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

e. After all the dough has been extruded onto trays, and the trays removed to the drying rack, clean all equipment.

A.8 Curing, cutting and weighing the igniters

a. After all the igniter dough has been extruded onto the plastic trays, the igniters shall be placed in a well ventilated (relative humidity < 20 %) area to dry. After approximately 24-28 h, the igniters should be dry enough to cut.

b. Cut all the igniter strands on the plastic trays to a length of (28,6 ± 3,2) mm. Continue to dry the cut igniters at the conditions described in step a. for another 24-48 h until they are dry to the touch.

c. Transfer the igniters from the plastic trays into a desiccator (relative humidity < 15 %). Place them directly onto the desiccant bed.

d. Continue to dry the igniters inside the desiccator. After approximately seven days, select ten igniters, and weigh them. The weight specification for the igniters is 0,190 g to 0,240 g. If eight out of ten igniters weigh in the specified range, the final dried state has been reached, and the igniters are ready for certification. If more than two igniters weigh over 0,240 g, continue to dry the igniters.

e. If more drying time is required, per step d., wait approximately 24-48 h, then select ten additional igniters. If eight out of the ten meet the weight specifications, the igniters are ready for certification. Due to varying conditions in desiccators, this process may take as long as two weeks, or more.

A.9 Certifying the igniters

a. Weigh all the igniters in the desiccator. If the igniter weighs less than 0,190 g, it is under weight, and shall be discarded. If the igniter weighs more than 0,240 g, it may be cut down to 25,4 mm long to achieve the weight specification. If the proper weight is not achieved within the length specification, the igniter shall be discarded. Cutting and weighing of the igniters shall be done in a dry environment (relative humidity < 20 %), since the igniters will absorb moisture when exposed to excess humidity. In addition, the igniters shall remain circular, and not flatten out while curing in order to fit inside the ignition coil. To ensure this, igniters shall be placed in a rigid plastic corrugated holder while being cut.

b. To certify a 400 g mixture batch, randomly select a sample of 20 igniters. If a larger mixture batch is made, the certification sample shall be increased accordingly. The 20 igniters selected shall be tested for the peak flame temperature, burn duration, and peak flame height. Each igniter tested shall develop a flame temperature of (1100 ± 90) °C. The igniter flame shall be sustained for (25 ± 5) s with a peak flame height of (6,5 ± 0,65) cm.

c. Igniters shall be tested in certified breathing air at standard atmospheric pressure. The temperature shall be measured by a type S thermocouple constructed with a 0,81 mm diameter wire. The thermocouple wire shall be centred geometrically 25,5 mm above the top of the igniter. To initiate the igniter, a voltage source capable of providing 15 A (r.m.s.) shall be connected to a 0,90 mm, bare nickel chromium wire. The wire shall have a nominal resistivity of 2,3 Ω/m and shall have sufficient length to wrap three, equally spaced turns around the igniter. In addition, the leads to the nickel chromium wire coil shall not exceed 32 mm to ensure proper ignition of the igniter. A calibrated ruler shall be placed in the test chamber to measure flame height.

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

e. To certify a batch of igniters perform the following steps for each of the 20 randomly selected igniters.

   1. Place the igniter in the nickel chromium wire coil.
   2. Pressurize the test chamber to standard atmospheric pressure with certified breathing air.
   3. Turn on the power to the igniter. When ignition is accomplished, turn power off.
   4. Record the 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) shall be obtained using a calibrated stop watch. The flame height is determined by measuring the maximum height of the flame above the apex.

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

f. The batch of igniters is acceptable for use when no more than one igniter out of the 20 tested fails the specified criteria (step b.). Once the batch of igniters is tested and certified, the average peak flame temperature and average burn shall be calculated, along with the standard deviation.

A.10 Waste disposal

Dispose of any waste generated from manufacturing, cutting or weighing igniters, including an entire batch that fails, per applicable hazardous waste/ environmental regulations.

A.11 Packaging and storing igniters

a. Package the igniters in a plastic storage container between layers of 3,2 mm thick (minimum) foam corrugated wrap. Place the igniters in the grooves of the corrugated wrap. The order of placement in the storage container shall be:

1. corrugated wrap with groove side up;
2. layer of igniters in grooves of corrugated wrap; and
3. corrugated wrap with groove side down.

Repeat steps 1. to 3. until the container is full. This placement will put two layers of corrugated wrap between each layer of igniters, and minimize movement when the box is moved or stored. To absorb any excess moisture which might affect the performance of the igniters, place desiccant packets on top of the igniters, inside the container.

b. To prevent the igniters from absorbing moisture during an extended storage period, place the packaged igniters in a desiccator with colour changing desiccant or other type humidity indicator. The igniters may be stored for an indefinite period of time, if the desiccant is changed regularly, or the humidity in the desiccator is kept below 18 %.

Bibliography

NASA STD 6001	Flammability, Odor and Off-gassing compatibility Requirements & Test Procedures for Materials That Support Combustion
ZZU.0336.028	Standard test method for the determination of the oxygen concentration limit during the combustion of polymer materials (English translation of original Russian title)
ISO/CD 14624-1	Space systems - Test Method for Upward Flammability of Materials

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ECSS Document Improvement Proposal

1. Document I.D.	2. Document date	3. Document title
ECSS-Q-70-21A	4 October 1999	Flammability testing for the screening of space materials

4. Recommended improvement (identify clauses, subclauses and include modified text or graphic, attach pages as necessary)

5. Reason for recommendation

6. Originator of recommendation

Name:	Organization:	
Address:	Phone: Fax: e-mail:	**7. Date of submission:**

8. Send to ECSS Secretariat

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