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STANDARD**

**NASA-STD-(I)-6001A**

**National Aeronautics and Space Administration  
Washington, DC 20546-0001**

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**FLAMMABILITY, OFFGASSING, AND COMPATIBILITY  
REQUIREMENTS AND TEST PROCEDURES**

**MEASUREMENT SYSTEM IDENTIFICATION:  
METRIC (INCH-POUND)**

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### FOREWORD

This Interim Technical Standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods to meet urgent program and project technical needs. This interim standard has the consensus of the developing Technical Working Group but does not have Agencywide concurrence required for a NASA technical standard.

This interim standard may be cited in contract, program, and other Agency documents as a technical requirement.

This document establishes requirements for evaluation, testing, and selection of materials that are intended for use in space vehicles, associated Ground Support Equipment (GSE), and facilities used during assembly, test, and flight operations. Included are requirements, criteria, and test methods for evaluating the flammability, offgassing, and compatibility of materials. Provisions of this standard will be included, as applicable, in all future contracts and programs involving space vehicles, payloads, and associated support equipment. NASA-STD-6001 was previously published as NHB 8060.1, Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion.

Requests for information, corrections, or additions to this standard should be submitted via “Feedback” in the NASA Technical Standards System at <http://standards.nasa.gov>.

*Original Signed by  
Gregory L. Robinson for*

04/21/2008

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Michael Ryschkewitsch  
NASA Chief Engineer

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Approval Date

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# FLAMMABILITY, OFFGASSING, AND COMPATIBILITY REQUIREMENTS AND TEST PROCEDURES

## 1. SCOPE

### 1.1 Purpose

This standard establishes National Aeronautics and Space Administration (NASA) program requirements for evaluation, testing, and selection of materials to preclude unsafe conditions related to flammability, offgassing, and fluid compatibility. Additional materials performance requirements may be specified in other program or NASA Center-specific documentation.

### 1.2 Applicability

**1.2.1** Materials intended for use in space vehicles, specified test facilities, and specified Ground Support Equipment (GSE) shall meet the requirements of this document.

**1.2.2** Responsible NASA Centers' materials and processes (M&P) organizations shall include applicable requirements of this document in their materials control programs.

*This standard may be cited in contract, program, and other Agency documents as a technical requirement. Requirements are indicated by the word "shall." Explanatory or guidance text is indicated in italics.*

**1.2.3** Tailoring of this standard for application to a specific program or project shall be formally documented as part of program or project requirements and approved by the Technical Authority.

## 2. APPLICABLE DOCUMENTS

### 2.1 General

*The documents listed in this section contain provisions that constitute requirements of this standard, as cited in the text of sections 4 through 7 and Appendix A.*

The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority.

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*The applicable documents are accessible via the NASA Technical Standards System at <http://standards.nasa.gov> or may be obtained directly from the Standards Developing Organizations or other document distributors.*

**2.2 Government Documents****NASA**

NASA-STD-(I)-5005	Standard for the Design and Fabrication of Ground Support Equipment
NASA-STD-(I)-6016	Standard Materials and Processes Requirements for Spacecraft
NASA/TM-2007-213740	Guide for Oxygen Compatibility Assessments on Oxygen Components and Systems
NPD 7100.8	Protection of Human Research Subjects
NPR 7100.1	Protection of Human Research Subjects

**Department of Defense**

MIL-PRF-25604	Propellant, Uns-Dimethylhydrazine
MIL-PRF-26536	Propellant, Hydrazine
MIL-PRF-26539	Propellants, Dinitrogen Tetroxide
MIL-PRF-27402	Propellant, Hydrazine-Uns-Dimethylhydrazine (50% N <sub>2</sub> H <sub>4</sub> – 50% UDMH)
MIL-PRF-27404	Propellant, Monomethylhydrazine
MIL-STD-2223	Test Methods for Insulated Electric Wire (Method 3007, Dry Arc-Propagation Resistance only)

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### 2.3 Non-Government Documents

#### ASTM International (ASTM)

ASTM D92-05a	Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
ASTM D240-02 (reapproved 2007)	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
ASTM D1310-01 (reapproved 2007)	Standard Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus
ASTM D2863-06a	Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D4809-06	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (High Precision Method)
ASTM E502-07	Standard Test Method for Selection and Use of ASTM Standards for the Determination of Flash Point of Chemicals by Closed Cup Methods
ASTM E1354-04a	Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
ASTM G72-01	Standard Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment
ASTM G74-01	Standard Test Method for Ignition Sensitivity of Materials to Gaseous Fluid Impact
ASTM G86-98a (reapproved 2005)	Standard Test Method for Determining Ignition Sensitivity of Materials to Mechanical Impact in Ambient Liquid Oxygen and Pressurized Liquid and Gaseous Oxygen Environments

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ASTM G124-95 (reapproved 2003)	Standard Test Method for Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres
ASTM G125-00	Standard Test Method for Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants

**International Organization for Standardization (ISO)**

ISO 14624-1:2003	Space systems — Safety and compatibility of materials — Part 1: Determination of upward flammability of materials
ISO 14624-2:2003	Space systems — Safety and compatibility of materials — Part 2: Determination of flammability of electrical-wire insulation and accessory materials
ISO 14624-3:2005	Space systems — Safety and compatibility of materials — Part 3: Determination of offgassed products from materials and assembled articles

**Society of Automotive Engineers International (SAE)**

SAE AS4373	Test Methods for Insulated Electric Wire (Method 508, Dry Arc-Propagation Resistance only)
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**2.4 Order of Precedence**

This document establishes requirements, but does not supersede nor waive established Agency requirements found in other documentation. Conflicts between this standard and other requirements documents shall be resolved by the responsible Technical Authority.

**3. ACRONYMS AND DEFINITIONS****3.1 Acronyms and Abbreviations**

°C	degree Celsius
°F	degree Fahrenheit
≥	equal to or greater than
≤	equal to or less than
>	greater than
<	less than

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μ	micro
%	percent
±	plus or minus
A-50	aerozine 50
ASTM	ASTM International (originally known as the American Society for Testing and Materials)
cal	calorie
cc	cubic centimeter
cm	centimeter
CO <sub>2</sub>	carbon dioxide
DSC	differential scanning calorimetry
ft	foot, feet
ft-lb	foot pound
FTIR	Fourier transform infrared spectroscopy
g	gram
GN <sub>2</sub>	gaseous nitrogen
GOX	gaseous oxygen
GSE	Ground Support Equipment
HDBK	handbook
hr	hour
IEC	International Electrotechnical Commission
in	inch
ISO	International Organization for Standardization
J	joule
JSC	Johnson Space Center
k	kilo
l	liter
lb	pound
lbf	pound-force
LOX	liquid oxygen
M&P	materials and processes
M	mega
m	meter
MAPTIS	Materials and Processes Technical Information System
mg	milligram
min	minute
ml	milliliter
MLW	maximum limit weight

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mm	millimeter
MMH	monomethylhydrazine
MOP	Maximum Operating Pressure
MSDS	Material Safety Data Sheet
MSFC	Marshall Space Flight Center
MUA	Materials Usage Agreement
N <sub>2</sub> H <sub>4</sub>	hydrazine
N	newton
NASA	National Aeronautics and Space Administration
NVR	nonvolatile residue
O <sub>2</sub>	oxygen
OCA	oxygen compatibility assessment
OSHA	Occupational Safety and Health Administration
oz	ounce
P	minimum contact pressure
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RMS	root mean square
rpm	revolutions per minute
SAE	Society of Automotive Engineers International
sec	second
SMAC	spacecraft maximum allowable concentration
STD	standard
T	toxic hazard index
TC	thermocouple
TM	technical memorandum
UDMH	unsymmetrical dimethylhydrazine
V	volt
v	linear surface velocity
VCS	voluntary consensus standard
W	watt

**3.2 Definitions**

*Test-specific definitions are also presented in descriptions of individual tests (section 7 and Appendix A).*

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Ambient (room) temperature: Room temperature is 23 ( $\pm 5$ ) °C [73 ( $\pm 9$ ) °F].

Arc: A continuous, luminous discharge of electric current crossing a gap between two conducting surfaces.

Arc tracking (Arc propagation): That phenomena whereby an arc between two or more wires, once initiated, will sustain itself through a conductive path provided by degradation of the insulation for a measurable length.

Assembled article: An assembled article could be any component or assembly of components that is not a single material.

Autoignition temperature: The lowest temperature at which a material will spontaneously ignite under specific test conditions.

Degradation: An adverse physical or chemical change in a substance.

Enriched oxygen environment: Any environment that contains >21 percent oxygen by volume.

Flash point: The lowest temperature, corrected to a barometric pressure of 101.3 kPa (14.7 psia) at which application of an ignition source causes the vapors of a specimen to ignite under specified conditions of test.

Gaseous fluid impact: Heat delivered to a specimen by rapid fluid compression; may also be referred to as pneumatic impact, rapid pressurization, or adiabatic compression.

Gaseous oxygen (GOX): Gaseous environment that contains  $\geq 99.5$  percent oxygen.

Hermetically sealed: Contained such that the leak rate does not exceed  $1 \times 10^{-4}$  cc/sec.

Liquid oxygen (LOX): Cryogenic liquid environment that contains  $\geq 99.5$  percent oxygen.

Mechanical impact: Energy delivered by a plummet that has been dropped from a pre-established height onto a striker pin in contact with a specimen.

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Offgassed product: An organic or inorganic compound evolved as a gas from a material or assembled article.

Offgassing: The evolution of gaseous products from a liquid or solid material into an atmosphere.

Oxygen Compatibility Assessment (OCA): A systematic approach for identifying and addressing the fire hazards in an oxygen system; this process emphasizes the evaluation of ignition mechanisms and the application of materials test data.

Single-barrier failure: A leak through a barrier within a component that permits the fluid to contact the materials directly behind the barrier. Single barriers include mechanical joints, e.g., B-nuts; O-rings, gaskets, and bladders; and metallic and nonmetallic diaphragms. Structural parts, such as pressure lines and tanks, welded or brazed joints, and redundant seals in series that have been pressure-tested individually before use are not considered to be single barriers.

Spacecraft Maximum Allowable Concentration (SMAC): The maximum concentration of an offgassed product that is allowed in the habitable area of the spacecraft for a specified duration.

Technical Authority: The Technical Authority provides technical checks and balances by assuring that safety and mission success, relevant technical standards, engineering work, and safety and reliability analysis products are being conducted properly in accordance with established, high-reliability processes independent of nontechnical program/project constraints.

Voluntary Consensus Standard (VCS): Technical standard that is developed or adopted by voluntary consensus standard bodies, both domestic and foreign.

Worst-case anticipated use environment: Most hazardous pressure, temperature, material thickness, and/or fluid exposure conditions.

## 4. EVALUATION AND TESTING OF MATERIALS

### 4.1 Material Evaluation Requirements

a. Materials used in habitable areas of spacecraft, including the materials of the spacecraft, stowed equipment, and experiments, shall be evaluated for flammability and offgassing.

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- b. All materials used in other areas shall be evaluated for flammability.
- c. Materials that are exposed to LOX, GOX, and other reactive fluids shall be evaluated for compatibility with the fluid in their use application.
- d. Materials exposed to pressurized breathing gases also shall be evaluated for offgassing.
- e. Electrical insulation materials also shall be evaluated for arc tracking.
- f. The worst-case anticipated use environment (most hazardous pressure, temperature, material thickness, and fluid exposure conditions) shall be used in the evaluation of material suitability.

*Materials that have been shown to meet the criteria of the required tests are acceptable for further consideration in design.*

*Whenever possible, materials should be selected that have already been shown to meet the test criteria in the use environment.*

*Existing test data are compiled in the NASA Marshall Space Flight Center (MSFC) Materials and Processes Technical Information System (MAPTIS). MAPTIS can be accessed at <http://maptis.nasa.gov/>.*

### 4.2 Materials Usage Agreement (MUA)

- a. Systems containing materials that have not been tested or do not meet the criteria of the required tests shall be verified to be acceptable in the use configuration by analysis or testing.
- b. An MUA shall be prepared in accordance with the MUA system described in NASA-STD-(I)-6016, Standard Materials and Processes Requirements for Spacecraft, for flight hardware; or NASA-STD-(I)-5005, Standard for the Design and Fabrication of Ground Support Equipment, for GSE.
- c. The MUA shall document the acceptance rationale.
- d. The MUA shall be submitted to the responsible NASA Center's M&P organization for approval.

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### 5. APPLICABLE MATERIAL TESTS

*The applicable material test depends on the environment to which the material is exposed. Applicable environments are habitable environments, LOX and GOX systems, breathing gases, and reactive fluids.*

a. Required tests shall be conducted on materials in their applicable exposure conditions.

b. To be considered acceptable for use without restriction, the materials shall pass the required tests.

*All nonmetals tested in accordance with NASA-STD-(I)-6001 should be retested every 10 years or as required by the responsible NASA Center's M&P organization.*

*Table 1 lists the required tests for each material use. Descriptions of these test methods are provided in section 7.*

**Table 1—Required Tests for Each Material Use**

ENVIRONMENT	TEST NUMBER	TITLE
Habitable Flight Compartments	1	Upward Flame Propagation
	4	Electrical Wire Insulation Flammability
	7	Determination of Offgassed Products <sup>1</sup>
	18	Arc Tracking
Other Areas <sup>2</sup>	1	Upward Flame Propagation
	4	Electrical Wire Insulation Flammability
	18	Arc Tracking
LOX and GOX Environments <sup>3,4</sup>	1	Upward Flame Propagation <sup>5</sup>
	17	Upward Flammability of Materials in GOX <sup>6</sup>
Breathing Gases <sup>4</sup>	1	Upward Flame Propagation
	7	Determination of Offgassed Products
Reactive Fluids	15	Reactivity of Materials in Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia
<sup>1</sup> Not required for materials inside hermetically sealed containers. <sup>2</sup> Includes all areas outside the habitable flight compartment. <sup>3</sup> Materials used in LOX or GOX environments shall be evaluated as described in section 6.3. <sup>4</sup> The need for an OCA, as described in section 6.3, shall be addressed for compressed air systems and pressurized systems containing enriched oxygen. <sup>5</sup> Required for nonmetals for pressures $\leq 345$ kPa ( $\leq 50$ psia). <sup>6</sup> Required for nonmetals for pressures $> 345$ kPa ( $> 50$ psia) and for all metals used in GOX and LOX		

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c. Materials that do not meet the criteria of the required tests and that are to remain candidates for use shall be verified to be acceptable in the use configuration by analysis or testing and specifically approved by the responsible NASA Center's M&P organization.

*Supplemental tests may be conducted to support the system hazard evaluation for materials that do not meet the criteria of the required tests; data based on other appropriate and applicable test methods also may be used to support the evaluation. In addition, supplemental tests may be required as an aid to the OCA process or as a result of the findings of the OCA process.*

*Table 2 lists the supplemental tests for each material use.*

**Table 2—Supplemental Tests for Each Material Use**

ENVIRONMENT	TEST NUMBER	TITLE
Habitable Flight Compartments	2	Heat and Visible Smoke Release Rates
	3	Flash Point of Liquids
	6	Odor Assessment
	10	Simulated Panel or Major Assembly Flammability
	-	Electrical Arc
Other Areas	2	Heat and Visible Smoke Release Rates
	3	Flash Point of Liquids
LOX and GOX Environments	13A	Mechanical Impact For Materials in Ambient Pressure LOX
	13B	Mechanical Impact for Materials in Variable Pressure LOX and GOX
	14	Gaseous Fluid Impact
	ASTM G72-01	Autogenous Ignition Temperature
	ASTM D240-02	Heat of Combustion
	ASTM G125-00	Oxygen Index
	-	Electrical Arc
	-	Frictional Heating
Breathing Gases	6	Odor Assessment
	-	Reactivity and Penetration of Materials due to Incidental Exposure to Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia
Reactive Fluids	3	Flash Point of Liquids

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d. When specified by the responsible NASA Center's M&P organization, materials shall be batch/lot tested until the effect of composition and materials processing variations are demonstrated to be insignificant to the characteristics being evaluated.

### 6. SYSTEM EVALUATIONS

a. System evaluations shall demonstrate the acceptability of configurations resulting from the use of flammable, incompatible, or offgassing materials.

b. Materials that can be exposed to reactive fluids as a result of a single-barrier failure shall be documented.

c. An engineering evaluation and analysis of test data shall be provided to demonstrate the acceptability of any configuration for which single-barrier failures are possible.

#### 6.1 System Flammability in Low-Pressure Air or Oxygen-Enriched Environments, Including Habitable Environments

**6.1.1** A system flammability evaluation shall be conducted if materials that fail to meet the criteria of Test 1 are proposed for use in human-occupied spacecraft, specified test facilities, or specified GSE.

*This evaluation can be conducted by analysis or by testing. JSC 29353, Flammability Configuration Analysis for Spacecraft Applications, provides guidelines for hardware flammability assessment and mitigation.*

**6.1.2** If the analytical approach is used, the following fire control guidelines shall be addressed and the results documented and submitted to the responsible NASA Center's M&P organization for evaluation:

a. The amount and arrangement of flammable materials are controlled to prevent the spread of fire in the vehicle; any potential fire is isolated in well-defined areas, by firebreaks or other techniques, without propagation paths to other areas.

b. The design ensures that ignition sources are eliminated or controlled.

c. The effects of an isolated fire on personnel in spacecraft crew-habitable modules are considered.

d. The rate and magnitude of pressure and temperature increase in any potential fire will not cause structural damage to the vehicle.

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**6.1.3** If the test approach is used, materials that do not meet the criteria of Test 1 shall be evaluated by a configuration test, such as Test 10, which evaluates the worst possible failure modes in the worst-case operating conditions.

**6.1.4** If the results of the evaluation are inconclusive and a major assembly flammability test, such as a crew module test, is required, the system design organization shall submit a test plan to the responsible NASA Center's M&P organization for approval before test.

### **6.2 Spacecraft Offgassing**

*System evaluation requirements for bulk materials/assembled articles are specified in section 7.3.*

*Total spacecraft offgassing evaluation is the responsibility of the NASA Toxicology Office.*

### **6.3 Material and Component Compatibility in LOX and GOX Environments**

**6.3.1** Materials, components, and systems used in LOX and GOX environments shall be evaluated using the approach shown in figure 1.

#### **6.3.2 OCA**

a. The need for an OCA shall be addressed for compressed air systems and pressurized systems containing enriched oxygen.

*Such systems are inherently less hazardous than systems containing pure oxygen; the hazard increases with oxygen concentration and/or increasing pressure.*

b. If it is determined that an OCA is not required, concurrence shall be obtained from the responsible NASA Center's M&P organization.

*This approach begins with pre-selection of materials based on flammability and combustion test data, followed by a flammability assessment. If the materials are determined to be nonflammable in their use configuration and environment and no additional material control is required, the materials may be used.*

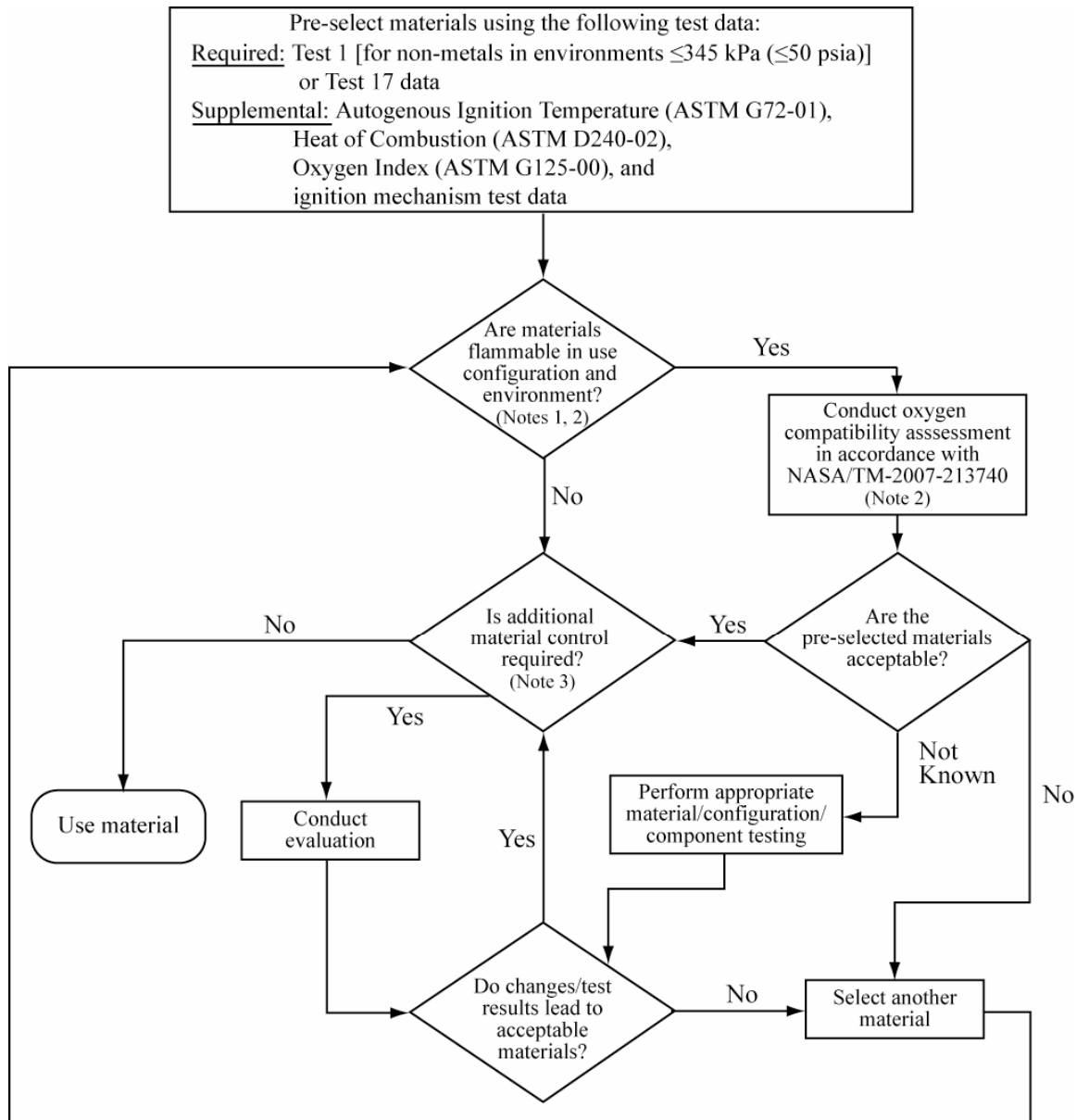
**6.3.3** If the materials are determined to be flammable, an OCA shall be performed in accordance with NASA/TM-2007-213740, Guide for Oxygen Compatibility Assessments on Oxygen Components and Systems.

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*The OCA is used to determine whether the material may be used or whether there is a need to perform supplemental material, configuration, or component testing.*



## Notes:

1. Data used to assess material flammability must be applicable to the specific configuration of the parts; therefore, data other than standard test data may be required.
2. Consult the responsible M&P organization to ensure that the testing data used to make flammability and ignitability assessments are applicable to the specific design configuration.
3. Additional material control refers to requirements from sources other than NASA-STD-(I)-6001, such as corrosion requirements.

**Figure 1—Approach for Selecting Materials, Components, and Systems used in LOX and GOX Environments**

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**6.3.4** Further details for several steps in the material and component evaluation process are:

a. Pre-Selection of Materials. As a minimum, previously untested nonmetallic materials shall be subjected to autogenous ignition temperature and heat of combustion testing.

*The objective of the pre-selection process is to choose materials that exhibit desirable flammability and combustion characteristics. For instance, materials that do not burn in the specific environment and configuration are preferred for oxygen service. In addition, nonmetals that have high autogenous ignition temperatures, low heats of combustion, and high oxygen indices are preferred for oxygen service. Other data that may be useful in the pre-selection of materials for LOX and GOX environments include data for specific ignition mechanisms, such as particle impact, gaseous fluid impact, and mechanical impact.*

b. Flammability Assessment. Data used to assess material flammability shall be applicable to the specific environment and configuration of the parts.

- (1) If the flammability or configuration of the materials is unknown, the materials shall be considered flammable.
- (2) The responsible NASA Center's M&P organization shall be consulted to ensure that the data used to make flammability assessments are applicable to the specific design configuration.

*In general, as pressure increases, all materials (metals, plastics, elastomers, lubricants, and contaminants) become flammable in 100 percent oxygen. In addition, almost all polymers are flammable in 100 percent oxygen at atmospheric pressure. Furthermore, the flammability of a material is very dependent upon its configuration. For instance, metals, including those that normally exhibit high resistance to ignition, are more flammable in oxygen when they have thin cross-sections, such as thin-walled tubing, or when they are finely divided, such as wire mesh or sintered filters. When assessing flammability, therefore, it is important to reference a cross-sectional view of each component that shows the configuration of all of the materials of construction.*

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### c. OCA

- (1) The responsible NASA Center's M&P organization shall be consulted to ensure that the data used to make ignitability assessments are applicable to the specific design configuration.
- (2) The results of the OCA shall be documented and submitted to the responsible NASA Center's M&P organization for concurrence.
- (3) An MUA, if applicable, shall be used to submit the OCA results.
- (4) The hardware developer shall verify that the materials assessed in the OCA reflect the as-built design.

*The OCA process described in NASA/TM-2007-213740 is a systematic approach that focuses on fire hazards. This process emphasizes the evaluation of ignition mechanisms and the application of materials test data.*

*Supplemental tests may be performed as an aid to the OCA process or as a result of findings of the OCA process. These tests may be material tests, configuration tests, or component tests. Guidelines for supplemental tests can be obtained from the responsible NASA Center's M&P organization.*

### 6.4 Materials Compatibility in Systems Containing Reactive Fluids

*Test 15 is intended to be a short-term exposure test.*

**6.4.1** A system evaluation shall be conducted for all systems containing reactive fluids.

**6.4.2** Materials used in system construction shall be evaluated for compatibility with the fluid to which they are to be exposed, as well as compatibility with the fluid decomposition products.

*The effects of single-barrier failures should be considered as part of this system evaluation.*

**6.4.3** Evaluations shall be supported by analysis, by Test 15 data, and when necessary, by more extensive long-duration and/or configuration-specific testing.

**6.4.4** The analytical approach shall examine all possible sources of runaway exothermic reactions, develop control methods, and document the results.

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*Possible initiation sources for runaway exothermic reactions include mechanical impact, rapid pressurization, sources of electrical energy, and other sources of heat.*

**6.4.5** The rationale for use of materials that fail to meet the criteria of Test 15 shall be documented and submitted to the responsible NASA Center's M&P organization for approval.

*Guidelines for configuration tests to evaluate runaway reactions in reactive fluid systems can be obtained from the responsible NASA Center's M&P organization.*

## 7. TEST METHODS

*Methods for required flammability, offgassing, and compatibility tests are presented in this section.*

- a. Tests shall be performed by certified test facilities.
  - (1) The test facility shall demonstrate good laboratory practices to produce accurate and repeatable test data.
  - (2) Good laboratory practices shall include calibration and maintenance procedures.
  - (3) At least every 2 years, test facilities shall demonstrate testing proficiency to maintain certification in accordance with Appendix B.
- b. Properly identified material for testing shall be provided by the responsible NASA Center or contractor hardware supplier and accompanied by a test request form similar to that provided in Appendix D.

*Alternatively, certified test facilities can be authorized by the test requester to procure the appropriate materials.*

- c. Material and Specimen Receipt and Preparation.
  - (1) Materials shall be accompanied by Material Safety Data Sheets (MSDSs) to comply with materials-handling requirements defined by the Occupational Safety and Health Administration (OSHA).
  - (2) Material specimens shall be visually inspected, and any flaws or contamination shall be noted in the test report.

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*Materials 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 the material to these and other contamination sources be controlled sufficiently to minimize variation in test results.*

- (3) Specimens shall be prepared in the proper dimensions.
- (4) Specimens shall be weighed and identified individually.
- (5) Specimens shall be cleaned to end-use specifications.
- (6) Specimens shall be inspected after preparation to ensure suitability for the specific test requested.
- (7) As a minimum, all fluids used for testing shall meet or exceed user specifications.

d. When there is a deviation from standard test parameters, such as nonstandard specimen preparation or test conditions, the test shall be identified as nonstandard.

*Table 3 lists the minimum quantities of material required to perform each test properly.*

**Table 3—Minimum Quantities of Materials Required for Testing for Each Atmosphere or Fluid**

MATERIAL TEST FORM <sup>1</sup>	TEST	MINIMUM QUANTITIES
Solids (sheet, rod, etc.)	1	6 specimens, 30 by 6.4 cm (12 by 2.5 in) by required thickness [thin films, 30 by 7.5 cm (12 by 3.0 in) by required thickness <sup>2</sup> ]
	2	18 specimens, 10 by 10 cm (4 by 4 in) by required thickness
	6	1500 cm <sup>2</sup> (232.5 in <sup>2</sup> ) total area or 15 g (0.5 oz)
	7	4000 cm <sup>2</sup> (620 in <sup>2</sup> ) total area or 40 g (1.4 oz)
	13	1000 cm <sup>2</sup> (155 in <sup>2</sup> ) total area, 0.64 cm (0.25 in) maximum thickness or individual specimen diameter of 1.75 cm (0.69 in)
	15	50 cm <sup>2</sup> (7.75 in <sup>2</sup> ) total area or 20 g (0.7 oz) by required thickness
	17	15 specimens, 10.2-cm (4-in) (minimum) by 0.32-cm (0.125-in) diameter rods
Coatings (Paints, Inks, and Adhesives)	1	Sufficient to cover [paints, 6 specimens, 30 by 6.4 cm (12 by 2.5 in) by required thickness]
	2	18 specimens, 10 by 10 cm (4 by 4 in) by required thickness
	6	1500 cm <sup>2</sup> (232.5 in <sup>2</sup> ) total area or 500 ml (16.9 oz)

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	7	4000 cm <sup>2</sup> (620 in <sup>2</sup> ) total area or 500 ml (16.9 oz)
	13	500 ml (16.9 oz)
	15	500 ml (16.9 oz)
Foams	1	6 specimens, 30 by 6.4 cm (12 by 2.5 in) by required thickness
	2	18 specimens, 10 by 10 cm (4 by 4 in) by required thickness
	6	1500 cm <sup>2</sup> (232.5 in <sup>2</sup> ) total area
	7	4000 cm <sup>2</sup> (620 in <sup>2</sup> ) total area
	13	1000 cm <sup>2</sup> (155 in <sup>2</sup> ) total area [0.64 cm (0.25 in) maximum thickness]
	15	50 cm <sup>2</sup> (7.75 in) total area or 20 g (0.7 oz)
Insulated Wires	1	2 m (6.6 ft) in length
	4	10 m (33 ft) in length
	6	15 g (0.5 oz)
	7	40 g (1.4 oz)
	13	250 cm (98 in) in length
	15	1 m (3.3 ft) in length
	18	70 m (230 ft) in length
Special Requirement	3	As recommended by selected ASTM test method
	Gaseous Fluid Impact	As recommended by the OCA or by the test requester
	Autogenous Ignition Temperature	10 g (0.35 oz)
	Heat of Combustion	10 g (0.35 oz)
	Oxygen Index	As recommended by ASTM G125-00; when using ASTM D2863-06, 25 specimens, 15.2 cm by 6.4 cm (6 by 2.5 in) or equivalent amount of material
	Frictional Heating	As recommended by the OCA or by the test requester
	Particle Impact	As recommended by the OCA or by the test requester
<sup>1</sup> Actual test configurations and material quantities for material forms other than those listed. e.g., O-rings and seals, should be established and approved by the responsible NASA Center's M&P organization. <sup>2</sup> When influence of test frame on results is of concern, optional large thin films of 30 by 20 cm (12 by 8 in) by required thickness may be used, subject to the approval of the responsible NASA Center's M&P organization.		

**7.1 Upward Flame Propagation (Test 1)**

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### **7.1.1 Purpose**

*The purpose of this test is to determine if a material, when exposed to a standard ignition source, will self-extinguish and not transfer burning debris, which can ignite adjacent materials.*

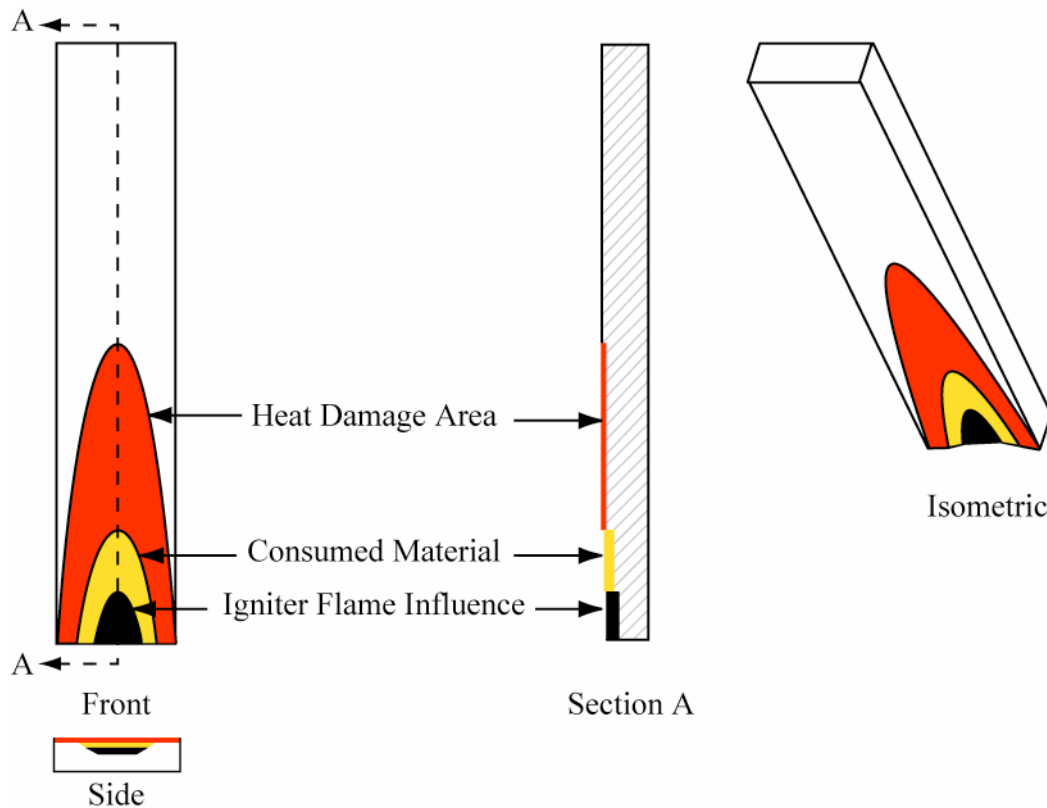
### **7.1.2 Test Summary**

- a. Test 1 shall evaluate the candidate material in the worst-case atmosphere to which the material could be exposed.
- b. Five test specimens, each with dimensions of 300 mm by 65 mm (12 in by 2.5 in) and tested one at a time, shall be mounted vertically in a test stand.
- c. The specimens shall be ignited at the bottom by an ignition system and allowed to burn until each self-extinguishes.
- d. The burn length, i.e., the linear distance of consumed specimen, shall be measured.
- e. Both the burn length and whether or not ignition of the paper occurred by a transfer of burning debris shall be recorded on the test report (figure 2.)

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**Figure 2—Flammability Post-Test Specimen**

### 7.1.3 Test Criteria

a. The flammability test specimens shall meet the acceptance criteria of the test and be considered self-extinguishing if both of the following conditions are met:

- (1) No specimen material of the five standard-sized specimens burns >15 cm (6 in).
- (2) No test specimen propagates a flame by the transfer of burning debris.

b. Failure of any one specimen to meet both criteria [7.1.3.a.(1) and (2)] shall constitute failure of the material.

### 7.1.4 Test Method

The test method defined in ISO 14624-1, Space systems — Safety and compatibility of materials — Part 1: Determination of upward flammability of materials, shall be followed for this test, with the following exceptions, clarifications, and additions:

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*The relevant ISO 14624-1 section is included in parentheses.*

a. Exception (throughout): One test shall consist of five replicate, identical specimen ignitions.

*The term “specimen” is used to indicate one standard-sized section of a material used for testing. The Upward Flame Propagation Test requires five specimens to produce one standard test.*

b. Clarification (section 3.1): Burn length: the distance from the bottom of the specimen to the farthest evidence of damage to the test specimen caused by flame consumption as determined by visual observation, post-test examination, video of burn, and/or other means.

c. Addition (section 3.8): Maximum Oxygen Concentration: The maximum oxygen concentration at which at least five specimens pass the acceptance criteria of this test.

d. Exception, addition (section 4):

- (1) In addition, the ignited specimens shall not ignite the paper (produce flaming combustion) below the test specimens, which would indicate that the transfer of burning debris would have sufficient energy to ignite adjacent materials.
- (2) 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 shall be conducted without the paper.

*This is done because the burning paper can inhibit the burning of the test specimen.*

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

e. Addition (section 4): Materials shall be tested in the worst-case configuration.

*If the worst-case environment is uncertain, determination of the maximum oxygen concentration is recommended.*

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## f. Additions (section 5.1):

- (1) The test atmosphere shall consist of a mixture of oxygen and nitrogen, with the oxygen level being the highest that the material could witness in use conditions.
- (2) The test gases shall be mixed thoroughly before testing a specimen.

*The gases may be premixed before introduction of the gases into the test chamber or mixed inside the test chamber.*

## g. Additions (section 5.1):

- (1) When gases are mixed in the chamber, they shall be circulated with a fan until a homogeneous mixture is attained, as determined by a gas analyzer.
- (2) The test gases shall be verified for conformity with the specification (including accuracy) for oxygen concentration to within +1.0 percent -0 percent of reading.

h. Addition (section 6.1): *Testing may be conducted in a fume hood in air if the above conditions can be met and the test results are verified against test chamber testing results.*

## i. Addition (section 6.1): Air shall not be allowed to flow during tests.

j. Clarification (section 6.3): *The term "ambient conditions" refers to an oxygen concentration of 20.9 percent, a pressure of 101.4 kPa (14.7 psia), and a temperature of 23 (±5) °C [73 (±9) °F].*

k. Exception (section 7.1, table 1): The minimum quantity of materials required for testing shall be as indicated in table 3 of this document.

## l. Exception (section 8.1b): All specimens shall be video recorded during testing.

m. Exception (section 8.2.1): The test specimen shall be subjected to vacuum no less than 1 min but no more than 3 min.

n. Exception (section 8.2.1): The igniter shall be retracted from the test specimen once the igniter extinguishes.

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o. Additions (section 8.2.2):

- (1) Any flames emanating from the paper below the specimen shall be observed and noted.
- (2) The paper shall be supported by a non-flammable, non-conducting screen material.
- (3) Flame jets and sparks emanating from the specimen during combustion shall be observed and recorded.

p. Addition: The test report (in the acceptable format) shall be submitted to MAPTIS.

### 7.2 Heat and Visible Smoke Release Rates (Test 2)

*Test 2 is now a supplemental test. A description of the test method is provided in Appendix A.1.*

### 7.3 Flash Point of Liquids (Test 3)

*Test 3 is now a supplemental test. A description of the test method is provided in Appendix A.2.*

### 7.4 Electrical Wire Insulation Flammability (Test 4)

*VCS adopted and tailored.*

#### 7.4.1 Purpose

*The purpose of this test is to determine whether an electrical wire insulation material, when exposed to a standard ignition source, will self-extinguish and not transfer burning debris, which can ignite adjacent materials.*

#### 7.4.2 Test Summary

a. The test shall evaluate the candidate wire insulation material in the worst-case atmosphere to which the wire could be exposed on a NASA mission.

b. Five test specimens, each a wire equivalent to the candidate wire and having a length of 1.2 m (48 in), with the active area being 300 mm (12 in) shall be tested one at a time and mounted at a 15-degree angle from vertical in a test stand.

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c. The specimens shall be ignited at the bottom by an ignition system and allowed to burn until each self-extinguishes.

d. The burn length, i.e., the linear distance of the consumed specimen, shall be measured, and both the burn length and whether ignition of the paper occurred by a transfer of burning debris shall be recorded on the test report.

### 7.4.3 Test Criteria

a. The wire test specimens shall meet the acceptance criteria of this test and be considered self-extinguishing if both of the following conditions are met:

(1) No specimen insulation material of the five tested burns >15 cm (6 in).

(2) No test specimen propagates a flame by the transfer of burning debris.

b. Failure of any one specimen to meet both criteria [7.4.3.a.(1) and (2)] shall constitute failure of the material.

*The term “specimen” is used to indicate one standard-sized strand of a wire used for testing. Five specimens produce a standard Electrical Wire Insulation Flammability Test.*

### 7.4.4 Test Method

The test method described in ISO 14624-2, Space systems — Safety and compatibility of materials — Part 2: Determination of flammability of electrical-wire insulation and accessory materials, shall be followed for this test, with the following exceptions, clarifications, and additions:

*The relevant ISO 14624-2 sections are included in parentheses.*

a. Exception (throughout): One test shall consist of five replicate, identical specimen ignitions.

b. Exception (throughout): The minimum quantity of material required for testing is listed in table 3 of this document.

c. Clarification (section 4.1): Burn length: the distance from the bottom of the specimen as it sits in the test stand to the farthest evidence of damage to the specimen's test insulation material caused by flame consumption as determined by visual observation, post-test examination, video of burn, and/or other means.

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d. Addition (section 4.3): Transfer of burning debris: movement of burning particles from a burning specimen to adjacent materials with sufficient energy to ignite the paper below the test specimen.

e. Addition (section 4): Maximum Oxygen Concentration: The maximum oxygen concentration at which at least five specimens pass the acceptance criteria of this test.

f. Exception (section 6.1): A standard test shall consist of five wire specimens tested.

g. Addition (section 6.1): In addition, the ignited wire test specimens shall not ignite the paper (produce flaming combustion) below the test specimens, which would indicate that the transfer of burning debris would have sufficient energy to ignite adjacent materials.

h. Addition (section 6.1): If, during a test, the paper used as an indication of the transfer of burning debris ignites because of burning debris, subsequent burns during testing of the same wire specimens shall be conducted without the paper.

*This is done because the burning paper can inhibit the burning of the wire test specimen.*

i. Additions (section 6.1):

(1) Failure of any one specimen shall constitute failure of the wire in that test environment.

(2) Wires shall be tested in the worst-case configuration.

*If the worst-case environment is uncertain, determination of the maximum oxygen concentration is recommended.*

j. Additions (section 6.2.1):

(1) The test atmosphere shall consist of a mixture of oxygen and nitrogen, with the oxygen level being the highest that the material could witness in use conditions.

(2) The test gases shall be mixed thoroughly before testing a specimen.

*The gases may be premixed before introduction of the gases into the test chamber or may be mixed inside the chamber.*

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- k. Additions (section 6.2.1):
  - (1) When gases are mixed in the chamber, they shall be circulated with a fan until a homogeneous mixture is attained, as determined by a gas analyzer.
  - (2) The test gases shall be verified for conformity with the specification (including accuracy) for oxygen concentration to within +1.0 percent -0 percent of reading.
- l. Addition (section 6.3.1): *Testing may be conducted in a fume hood if the above conditions can be met and the test results are verified against test chamber testing results.*
- m. Addition (section 6.3.1): Air shall not be allowed to flow during tests.
- n. Addition (section 6.3.3): *The term “ambient conditions” refers to an oxygen concentration of 20.9 percent, a pressure of 101.4 kPa (14.7 psia), and a temperature of 23 (±5) °C [73 (±9) °F].*
- o. Exception (section 6.5.1.4): All specimens shall be video recorded during testing.
- p. Addition (section 6.5.2.1): The test specimen shall be subjected to vacuum no less than 1 min, but no more than 3 min.
- q. Exception (section 6.5.2.1): The igniter shall be retracted from the test specimen once the igniter extinguishes.
- r. Additions (section 6.5.2.2):
  - (1) Flames emanating from the paper below the wire specimen shall be observed and noted.
  - (2) The paper shall be supported by a non-flammable, non-conducting screen material.
  - (3) Flame jets and sparks emanating from the specimen during combustion shall be observed and recorded.
- s. Exception (section 7): Alternate Wire Insulation Flammability Test in a Gas Flow Environment, Test B, shall not be performed as Test 4.

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t. Addition: The test report (in the acceptable format) shall be submitted to MAPTIS.

### 7.5 Electrical Connector Potting and Conformal Coating Flammability (Test 5)

*Deleted in previous version.*

### 7.6 Odor Assessment (Test 6)

*Test 6 is now a supplemental test. A description of the test method is provided in Appendix A.3.*

### 7.7 Determination of Offgassed Products (Test 7)

*VCS adopted and tailored.*

#### 7.7.1 Purpose

*The purpose of this test is to determine the identity and quantity of volatile offgassed products from materials and assembled articles.*

#### 7.7.2 Test Summary

- a. Test 7 shall determine the offgassing characteristics under standardized conditions for materials and assembled articles to be located within habitable environments.
- b. Specimens shall be placed into certified-clean containers and thermally conditioned for 72 ( $\pm 1$ ) hr at 50 ( $\pm 3$ ) °C [122 ( $\pm 5$ ) °F].
- c. After the thermal conditioning, the atmosphere inside the specimen container shall be analyzed to determine the offgassed compounds.
- d. Using the SMAC for each offgassed compound, the overall toxicity rating shall be determined.
- e. The overall rating of each material or assembled article shall determine the quantity of each material or the number of assembled article units that can be flown.
- f. For a material or assembled article, the total Toxic Hazard Index (T) values for all volatile offgassed products shall be less than 0.5.

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### 7.7.3 Test Criteria

- a. For a component or a material, the total T values for all volatile offgassed products shall be less than 0.5.
- b. All materials used in habitable flight compartments shall meet the offgassing requirements, using one of the following methodologies:

- (1) Assembled article: Summation of T values (total concentration in  $\text{mg}/\text{m}^3$ /SMAC in  $\text{mg}/\text{m}^3$ ) of all offgassed constituent products shall not exceed 0.5.
- (2) Hardware components evaluated on a materials basis.
  - A. Individual materials used to make up a component shall be evaluated based on the actual or estimated mass of the material used in the hardware component.
  - B. The total T value for all materials used to make up the component shall be less than 0.5.
- (3) More than one hardware component or assembly: If a single hardware component is tested or evaluated for toxicity but more than one is to be flown, the T value obtained for one unit times the number of flight units shall be less than 0.5.
- (4) Bulk materials and other materials not inside a sealed container: All materials shall be evaluated individually using the ratings in the MAPTIS database (<http://maptis.nasa.gov/>).

*MAPTIS specifies the maximum quantity and associated rating for each material code.*

### 7.7.4 Test Method

The test method described in the baseline ISO 14624-3, Space systems — Safety and compatibility of materials — Part 3: Determination of offgassed products from materials and assembled articles, shall be followed for this test, with the following exceptions, clarifications, and additions:

*The relevant ISO 14624-3 sections are included in parentheses.*

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a. Addition (section 3.4 note): *A current listing of SMAC values is maintained in MAPTIS at <http://maptis.nasa.gov/>.*

b. Addition (section 3): Primary Gas Standard: gas mixtures that have gravimetric or analytical traceability and to which all measurements are ultimately compared.

c. Addition (section 3): Trace: the result reported when the identified offgassed compound is present in less than reportable quantities.

d. Addition (section 3): Reportable quantities: This amount shall be determined by each analytical laboratory using appropriate scientific processes and techniques and be based on analyzed concentrations of the specific compound.

*Compounds that have been identified, but for which the specific compound is unavailable as a standard, may have reportable quantities based on analyzed concentrations of a representative compound.*

e. Addition (section 3.5): T Value Calculations:

*The calculation of the toxic hazard index uses the free volume (spacecraft volume) of the habitable area of the craft under consideration. For the Space Shuttle Orbiter, this volume is 65 m<sup>3</sup> (2300 ft<sup>3</sup>); for the International Space Station (ISS), this volume is 118 m<sup>3</sup> (4170 ft<sup>3</sup>); and for the Constellation Orion Crew Exploration Vehicle, this volume is anticipated to be 15 m<sup>3</sup> (530 ft<sup>3</sup>). For habitable volumes not defined herein, contact the responsible NASA Center's M&P organization.*

*SMAC is the maximum concentration of an offgassed product that is allowed in the habitable area of the spacecraft for a specified duration.*

*SMAC values for each offgassed constituent are reported in mg/m<sup>3</sup>. (Unless otherwise specified, all calculations use 7-day SMACs as identified by the NASA Toxicology Office.)*

(1) Calculations for 45.36 kg (100 lb) of material shall be:

Q = Amount for each offgassed constituent in micrograms (µg)

M = Mass of material tested (g)

TX1 = Reported amount for each offgassed constituent in micrograms of constituent per gram of material tested (µg/g)

TX2 = Amount for each offgassed constituent in milligrams per cubic meter (mg/m<sup>3</sup>) for 45.36 kg (100 lb) of material

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TC = T value for each offgassed constituent for 45.36 kg (100 lb) of material (dimensionless)

T100 = Summation of the TC values of all offgassed constituents detected for 45.36 kg (100 lb) of material (dimensionless)

MLW<sub>kg</sub> = Maximum Limit Weight in kilograms of material

MLW<sub>lb</sub> = Maximum Limit Weight in pounds of material

*For Test 7, TX1 and TX2 calculations are expressed only in metric units of measure.*

Calculation of TX1:

$$TX1\left(\frac{\mu\text{g}}{\text{g}}\right) = \frac{Q(\mu\text{g})}{M(\text{g})} \quad (\text{Eq. 1})$$

Calculation of TX2: Convert  $\mu\text{g/g}$  to  $\text{mg/m}^3$

$$TX2\left(\frac{\text{mg}}{\text{m}^3}\right) = TX1\left(\frac{\mu\text{g}}{\text{g}}\right) \times \left(\frac{45.36 \text{ kg}}{\text{Spacecraft volume}(\text{m}^3)}\right) \quad (\text{Eq. 2})$$

Simplification yields:

$$TX2\left(\frac{\text{mg}}{\text{m}^3}\right) = TX1\left(\frac{\mu\text{g}}{\text{g}}\right) \times \left(\frac{45.36 \left(\text{kg} = \left(\frac{\text{g} \times \text{mg}}{\mu\text{g}}\right)\right)}{\text{Spacecraft volume}(\text{m}^3)}\right) \quad (\text{Eq. 3})$$

$$TX2\left(\frac{\text{mg}}{\text{m}^3}\right) = \left(\frac{(TX1 \times 45.36)(\text{mg})}{\text{Spacecraft volume}(\text{m}^3)}\right) \quad (\text{Eq. 4})$$

Calculation of TC:

$$TC = \frac{TX2\left(\frac{\text{mg}}{\text{m}^3}\right)}{\text{SMAC}\left(\frac{\text{mg}}{\text{m}^3}\right)} \quad (\text{Eq. 5})$$

Calculation of T100:

$$T100 = \sum_{n=1}^n TC_n, \text{ for } n \text{ TC values} \quad (\text{Eq. 6})$$

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Calculation of the maximum limit weight (MLW):

$$MLW_{kg} = \frac{0.5}{T100} \times 45.36 \text{ kg} \quad (\text{Eq. 7})$$

$$MLW_{lb} = \frac{0.5}{T100} \times 100 \text{ lb} \quad (\text{Eq. 8})$$

(2) Calculation for assembled articles shall be:

*All assembled articles should be tested in the intended flight configuration.*

Q = Amount for each offgassed constituent in micrograms (μg)

TC = T value for each offgassed constituent (dimensionless)

T = Summation of the TC values of all offgassed constituents detected (dimensionless)

Calculation of the TC:

$$TC = \left( \frac{\left( Q(\mu\text{g}) \left( \frac{1(\text{mg})}{1000(\mu\text{g})} \right) \right)}{\text{Spacecraft volume}(\text{m}^3)} \right) \times \left( \frac{1}{\text{SMAC} \left( \frac{\text{mg}}{\text{m}^3} \right)} \right) \quad (\text{Eq. 9})$$

Calculation of the T:

$$T = \sum_{n=1}^n TC_n, \text{ for } n \text{ TC values} \quad (\text{Eq. 10})$$

Calculation of the maximum number of assembled articles (must round down):

$$\text{Total Number of Assembled Articles} = \frac{0.5}{T} \quad (\text{Eq. 11})$$

f. Exception (section 3.11): *Room temperature is equal to 23 (±5) °C [73 (±9) °F].*

g. Clarification (section 6.1): *The test atmosphere should be at least a volume fraction of 20.9 (±2) percent for oxygen with the balance nitrogen or argon, and the test pressure should be ±15 kPa (±2.18 psi) of the ambient pressure of the test facility.*

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h. Addition (section 6.1 note): *Batteries or assembled articles containing batteries should be tested in an inert atmosphere to reduce the risk of generating an explosive gas mixture. The batteries or assembled articles containing batteries tested in an inert atmosphere do not need to be tested again in an oxygen atmosphere for toxic offgassing,*

i. Clarification, addition (section 7.3):

*Analytical instrumentation, not specified; however, capable of the identification and quantification of all offgassed products at, or below, their SMAC concentrations when tested at a test-material-mass-to-specimen-container-volume ratio of 5.0 ( $\pm 0.25$ ) g/l.*

- (1) If the instrumentation cannot achieve this sensitivity, the minimum reportable concentration (reporting limit) for those offgassed products (except for formaldehyde) shall be reported.
- (2) For formaldehyde, the analytical technique shall be capable of detecting a concentration of 0.1 ppm or current SMAC.

*For Test 7, the test-material-mass-to-specimen-container-volume ratio is only expressed in metric units of measure.*

*The recommended analytical instruments include a gas chromatograph, primarily using a flame ionization detector, a gas chromatograph/mass spectrometer, and an infrared spectrophotometer. Some analytical compounds may be more difficult to determine; therefore, special methods may be required to identify and quantify these compounds. For example, the determination of formaldehyde may be performed using the proposed method of trapping on 2,4-dinitrophenylhydrazine cartridges for derivation and subsequent analysis by High Performance Liquid Chromatography.*

*In some cases, the reporting limit for a compound is greater than the SMAC for that compound, but the ability to meet the SMAC requirement is known to be crucial. To determine if the compound offgasses at the SMAC, it is necessary to test more than the standard test-material-mass-to-specimen-container-volume ratio of 5.0 ( $\pm 0.25$ ) g/l. The quantity of test material should be increased proportionally from the test-material-mass-to-specimen-container-volume ratio of 5.0 ( $\pm 0.25$ ) g/l to a quantity that will allow the analysis to meet the SMAC requirement.*

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*Example:*

*Benzene SMAC = 100 ppb*

*Reporting limit = 500 ppb*

*Standard material weight per chamber volume = 5 g/l*

$$\frac{5 \text{ g/l}}{100 \text{ ppb}} = \frac{X \text{ g/l}}{500 \text{ ppb}}$$

*X = Necessary material weight per chamber volume = 25 g/l*

j. Addition (section 8.2.1):

*Materials should meet a test-material-mass-to-specimen-container-volume ratio of 5.0 ±0.25 g/l. If the specimen weight cannot be met, the maximum practical quantity of specimen, at least 750 (±50) cm<sup>2</sup>/l of test chamber volume is tested, with the actual specimen weight and surface area reported.*

*For Test 7, specimen maximum practical quantity is only expressed in metric units of measure.*

k. Addition (section 8.2):

Unless the requester specifies a post-cure duration apart from the manufacturer's cure, the material shall be artificially aged by performing a post-cure (in addition to the manufacturer's cure) under open-air, ambient conditions for a minimum of 14 days.

The duration of the post-cure shall be reported.

l. Additions (section 8.2.3):

(1) Liquids and semi-solids shall be placed in suitable non-reactive vessels.

(2) The approximate total specimen surface area shall be reported.

m. Addition (section 8.3): *Pre- and post-test photographs may be taken when needed or requested by the test requester or test lead.*

n. Additions (section 9.4):

(1) The methods of quantitative analysis shall be traceable to primary gas standards.

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- (2) When available, standards used to quantify specific compounds shall be traceable to the national, international, or intrinsic standard.
- o. Exception (section 10.2): The specimen container shall be cooled to 23 ( $\pm 5$ ) °C [73 ( $\pm 9$ ) °F].
  - p. Addition (section 10.2): If any strong odors are detected during the Test 7 procedures, the test lead shall note this and shall recommend that Test 6 (Odor Assessment) be performed.
  - q. Addition: The test report (in the acceptable format) shall be submitted to MAPTIS.
  - r. Exception (section 13.1): Ethyl alcohol, methyl alcohol, tetrachloroethylene, tetrachloromethane, and acrylonitrile shall be measured to within 30 percent of the specified concentrations.
  - s. Exception, addition (table 1): *The analysis of furfural in Mix B is not required; however, this compound is useful as a diagnostic tool because it presents a meaningful challenge to the analytical system.*
  - t. Exception (Annex B): *Annex B is not applicable to Test 7.*
  - u. Clarification (Annex C.3): Ratings shall be based on the MLW:

Materials:

K = MLW of 100 lb or greater

H = MLW of 50 to 100 lb

A = MLW of 10 to 50 lb

V = MLW of 5 to 10 lb

X = MLW of 0 to 5 lb

Assemblies:A = Summation of T  $\leq 0.5$ .X = Summation of T  $> 0.5$ .**7.8 Flammability Test for Materials in Vented or Sealed Containers (Test 8)***Deleted.*

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### **7.9 Electrical Overload for Sealed Containers (Test 9)**

*Deleted in previous version.*

### **7.10 Configurational Flammability (Test 10)**

*Test 10, formerly titled Simulated Panel or Major Assembly Flammability Test, is now a supplemental test. A description of the test method is provided in Appendix A.4.*

### **7.11 Guidelines for Simulated Crew Bay Configuration Flammability Verification Test (Test 11)**

*Deleted in previous version.*

### **7.12 Total Spacecraft Offgassing (Test 12)**

*Deleted.*

### **7.13 Mechanical Impact for Materials in Ambient Pressure LOX (Test 13A) and Mechanical Impact for Materials in Variable Pressure LOX and GOX (Test 13B)**

*Tests 13A and 13B are now supplemental tests. Descriptions of the test methods are provided in Appendix A.5.*

### **7.14 Pressurized Gaseous Oxygen Pneumatic Impact for Nonmetals (Test 14)**

*Deleted. A similar test method for components is described in Appendix A.6.*

### **7.15 Reactivity of Materials in Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia (Test 15)**

#### **7.15.1 Purpose**

*Test 15 is a short-term exposure test that identifies changes resulting from exposure to fluids that degrade either the material or the fluid or produce a reaction, which would cause the pressure in a closed system to rise. As described herein, Test 15 is applicable to the hydrazine family of fuels, nitrogen tetroxide and mixed oxides of nitrogen, and ammonia. Requirements for compatibility of materials with other aerospace fluids are contained in other documents, such as NASA-STD-(I)-6016.*

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*This test is comprised of a screening test lasting 2 hr, followed by a short-term immersion test lasting 48 hr.*

Appropriate long-term tests shall be conducted for materials with long-term exposure to fuels, oxidizers, and other hazardous fluids.

*The responsible NASA Center's M&P organization should be consulted for guidance related to long-term exposure. Information on reactivity of materials with aerospace fluids may also be obtained using other tests such as accelerated rate calorimetry, isothermal microcalorimetry, or differential scanning calorimetry (DSC).*

*The test method described in Appendix A.7 is a supplemental test procedure for determining the effects of incidental exposure (minor amounts, such as a splash) of aerospace fluids on materials. Incidental exposure time is considered to be  $\leq 240$  min.*

### 7.15.2 Test Criteria

*This test is used to determine and document the reactivity of a material and fluid in comparison to a reference material; therefore, test criteria are dependent on the intended use environment and configuration of the material.*

*Section 7.5.12 addresses failure criteria.*

### 7.15.3 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Degradation: An adverse physical or chemical change in a substance.

Screening (beaker) test: A test performed with a small amount of material and fluid to screen for gross reactivity.

Immersion test: A test in which the fluid covers the entire specimen for the duration of the test in a sealed container with pressure measurement.

Reaction: A chemical change in which a substance decomposes, combines with other substances, or interchanges constituents with other substances.

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### 7.15.4 Test Conditions

#### a. Screening Test.

- (1) The standard test conditions for the screening test shall be ambient temperature and pressure of the test facility.
- (2) If a material is used above the test temperature, additional testing at the maximum use temperature shall be performed.

*The test duration is 2 hr, but in the case of gross reactivity, the test may be terminated early at the discretion of the test lead.*

#### b. Immersion Test.

- (1) For hydrazine, monomethylhydrazine (MMH), unsymmetrical dimethylhydrazine (UDMH), aerazine 50 (A-50), and nitrogen tetroxide and the mixed oxides of nitrogen, the standard test conditions for the immersion test shall be  $71 (\pm 3) ^\circ\text{C}$  [ $160 (\pm 5) ^\circ\text{F}$ ] and the vapor pressure of the fluid at that temperature.

*The elevated temperature of the immersion test is used to allow comparison of results with historical data. Elevated temperatures accelerate a reaction, make it measurable in a short time, and/or show the effects of elevated temperature on the pressure and post-test material and fluid analysis.*

- (2) For ammonia, the test temperature shall be  $30 (\pm 3) ^\circ\text{C}$  [ $86 (\pm 5) ^\circ\text{F}$ ], and the test pressure shall be its vapor pressure at that temperature.

*The test duration is 48 hr from the onset of heating, but the test may be terminated early in the case of gross reactivity or of a pressure rise that may cause the immersion tube to relieve.*

### 7.15.5 Test Fluids

Unless otherwise specified,

- a. Hydrazine shall meet the requirements of MIL-PRF-26536, Propellant, Hydrazine.
- b. MMH shall meet the requirements of MIL-PRF-27404, Propellant, Monomethylhydrazine.

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- c. UDMH shall meet the requirements of MIL-PRF-25604, Propellant, Uns-Dimethylhydrazine.
- d. A-50 shall meet the requirements of MIL-PRF-27402, Propellant, Hydrazine- Uns-Dimethylhydrazine (50% N<sub>2</sub>H<sub>4</sub> – 50% UDMH)
- d. Nitrogen tetroxide and mixed oxides of nitrogen shall meet the requirements of MIL-PRF-26539, Propellants, Dinitrogen Tetroxide.
- e. Ammonia shall be procured with a stated purity of 99.99 percent (liquid phase).

**7.15.6 Specimen Preparation**

*The goal of material testing is to simulate, as close as possible, the actual usage. To this end, the material preparation should employ the same cleaning and preparation processes, e.g., surface finish, porosity, heat treatment, that are expected to be used on the materials in the field.*

- a. Solid and foam materials shall be cut to 4 by 1 by 0.15 cm (1.6 by 0.4 by 0.06 in) to obtain a specimen measuring 25 ( $\pm 5$ ) cm<sup>2</sup> [3.9 ( $\pm 0.8$ ) in<sup>2</sup>] specimen.

*During specimen preparation, consideration should be given to edge effects of the specimen, e.g., cut ends of composite structures, insufficient application of coatings.*

*Specimens are prepared to a geometric surface area; however, actual surface area may be greater.*

- b. Greases, semisolids, and liquids shall be applied onto both sides of a tared, wedge-shaped 304L stainless steel substrate, the tare weight of which shall be determined to an accuracy of  $1.0 \times 10^{-4}$  g.

- c. Electrical insulation from wires and cables shall be stripped to prepare a specimen measuring 25 ( $\pm 5$ ) cm<sup>2</sup> [3.9 ( $\pm 0.8$ ) in<sup>2</sup>] specimen of the insulation.

- d. Inks, adhesives, coatings, primers, etc.

- (1) Test materials shall be applied in the end-use thickness onto abraded 4- by 1- by 0.15-cm (1.6- by 0.4- by 0.06- in) 304L stainless steel substrates.

- (2) Any requested cures shall be performed.

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- (3) A default thickness of 0.013 cm (0.005 in) shall be used if the adhesive end-use thickness is not specified.
- (4) Sufficient substrates shall be coated to achieve a 25- ( $\pm 5$ -) cm<sup>2</sup> [3.9- ( $\pm 0.8$ -) in<sup>2</sup>] specimen.
- e. Heat-shrinkable tubing.
  - (1) Tubing shall be pre-shrunk in accordance with manufacturer's instructions to simulate actual-use conditions.
  - (2) Tubing shall be cut to achieve a surface area of 25 ( $\pm 5$ ) cm<sup>2</sup> [3.9 ( $\pm 0.8$ ) in<sup>2</sup>].
- f. Pressure-sensitive tapes shall be applied to both sides of three 4- by 1- by 0.15-cm (1.6- by 0.4- by 0.06-in) 304L stainless steel substrates to achieve a surface area of 25 ( $\pm 5$ ) cm<sup>2</sup> [3.9 ( $\pm 0.8$ ) in<sup>2</sup>].
- g. Segments shall be cut, or an appropriate number of O-rings and irregularly shaped items shall be used to achieve a surface area of 25 ( $\pm 5$ ) cm<sup>2</sup> [3.9 ( $\pm 0.8$ ) in<sup>2</sup>].
- h. Specimens shall be cleaned and dried to end-use specifications.
- i. The specimen's mass shall be determined, and the approximate surface area shall be reported. Any flaws or residual contamination shall be inspected and reported.
- j. A reference specimen shall be prepared for the immersion test.

**7.15.7 Test System**

*This test requires the handling of hazardous fluids and has the potential to produce energetic events, such as fire, thermal runaway, or explosion. Testing should be carried out with the appropriate engineering controls and protective equipment.*

*The test system for the screening test should consist of a glass beaker in a fume hood approved for the handling of the test fluid.*

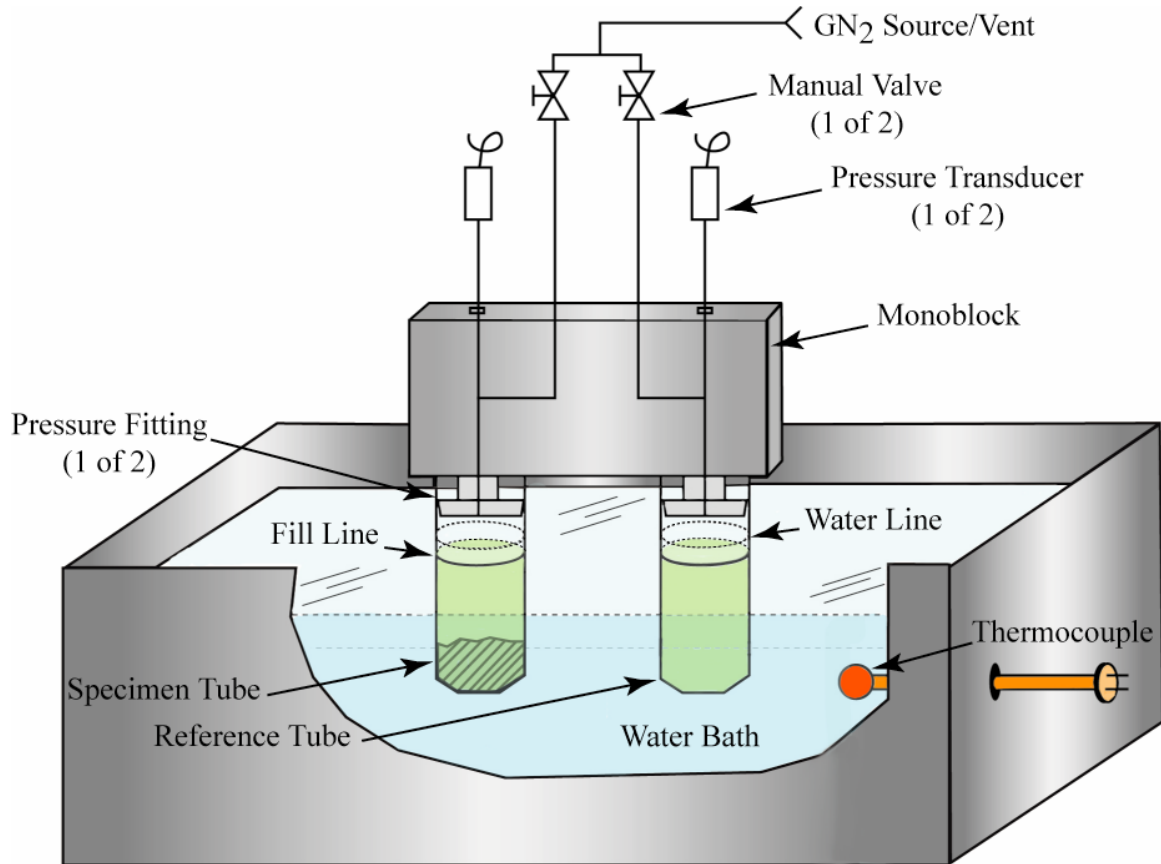
- a. The test system for the immersion test (figure 3) shall consist of one reference and one specimen immersion tube, each constructed of borosilicate glass and instrumented with a pressure transducer.
- b. The total ullage volume above the fill line shall be known and sufficient for accurate pressure measurement.

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- c. The remainder of the system shall be constructed of 304L stainless steel.
- d. The immersion tubes shall be maintained in a temperature-controlled water bath instrumented with at least one thermocouple (TC) positioned in the bath near the immersion tubes.



**Figure 3—Immersion Test System for Test 15**

- e. Test data, consisting of time, temperature, and pressure, shall be recorded at appropriate intervals throughout the test.
- f. The immersion system shall have provisions for inert atmosphere purging, filling operations, and cleaning.

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*Analytical techniques for post-test analysis of the fluid and material include nonvolatile residue (NVR), gas chromatography, ion chromatography, DSC, or Fourier transform infrared spectroscopy (FTIR).*

### 7.15.8 Pre-Test Procedure

- a. The fluid to be used in testing shall be analyzed and verified to meet the required specifications before use.
- b. All pertinent information for the test, e.g., specimen identification, composition, pre-test mass and dimensions, and fluid analysis results, shall be recorded.
- c. Reference/pre-test photos of the specimens shall be taken.
- d. The test system shall be clean and all the measuring devices in current calibration.

### 7.15.9 Test Procedure

*The Test 15 convention is to express test specimen weight and volume in metric units only.*

- a. Screening Test Procedure.
  - (1) A test specimen weighing  $\leq 0.25$  g shall be placed in the glass container.
  - (2) The test fluid shall be added drop by drop, slowly at first, and observed for any evidence of gross reactivity.
  - (3) If no gross reactivity is observed, the remainder of the test fluid (typically 10 ml total) shall be added.
  - (4) The specimen shall be observed for visible signs of reaction at the beginning and periodically during the test.

*The screening test may be stopped at signs of gross reactivity.*

- (5) At the end of the 2-hr exposure:
  - A. The specimen shall be removed from the fluid.
  - B. Observations shall be recorded.

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- C. Post-exposure mass and dimensions shall be taken when possible.
- D. Post-test visual observations shall be made using a set of defined standard terms (table 4).

**Table 4—Standard Descriptive Terms and Definitions for Test 15 Post-Test Analysis**

DESCRIPTIVE TERM	DEFINITION
Adherent	Bonded or clinging to the surface of a material
Brittle	Easily fractured or broken, not malleable or ductile
Bubble	To form gaseous products
Char	To darken appreciably in color, as in oxidation
Decompose	To break down into component parts or disintegrate, either partially or completely
Degradation	An adverse physical or chemical change in a substance
Discolor	To alter the color
Dissolve	To pass into solution with little or no decomposition
Firm	Stiff and unyielding to pressure
Flexible	Capable of being bent; pliable
Friable	Property of a substance capable of being easily rubbed, crumbled, or reduced to powder
Frothing	A mass of bubbles adhering to the liquid surface; foam
Hard	Resistant to pressure, not readily penetrated, firm
Matte	Having a dull, nonreflective surface or finish
No Visible Reaction	No visual evidence of change
Opaque	Does not transmit light
Pitted	Marked by pits or small depressions, either regular or irregular
Powder	Ground, dispersed solid particles
Reaction	A chemical change in which a substance decomposes, combines with other substances, or interchanges constituents with other substances
Reactive Fluid	A fluid that readily responds to a stimulus through reaction
Rigid	Not bending; inflexible
Rough	A bumpy, uneven surface
Shape	The characteristic bulk configuration or form
Smooth	Having a surface free from irregularities, projections, or roughness
Soft	Yielding readily to pressure or weight
Solid	Of definite shape and volume; a single piece
Swell	To increase in size or volume as a result of liquid absorption
Tacky	Adhesive or gummy to the touch
Translucent	Transmits light but does not permit the perception of images
Transparent	Transmits light to the extent that images can be perceived
Woven	Constructed from an interlacing of webs or strands
Wrinkled	Ridges or creases on surface

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*If the material is determined to be reactive, it does not continue to the immersion test.*

*If there is slight or no reactivity observed, the test lead may recommend the material be tested in the immersion test.*

### b. Immersion Test Procedure.

- (1) Both the test specimen and the reference material specimen shall be exposed to the same fluid in their respective containers.
- (2) For nonmetallic specimens, polytetrafluorethylene shall be used as the reference material.
- (3) For metallic specimens, 304L stainless steel shall be the reference material.
- (4) The specimen and the reference materials shall be placed in the appropriate immersion tube and then purged with nitrogen to remove air.
- (5) The system shall be checked for leaks, and sufficient test fluid (~25 ml) shall be added up to the fill line to cover the specimen completely to produce the same ullage space in the specimen and the reference tubes.
- (6) The pressure and temperature recording system shall be activated.
- (7) The immersion tubes shall be placed in the water bath.
- (8) Heating of the bath shall be ~0.25 °C (~0.32 °F)/min.
- (9) When not in use, the system shall be maintained under dry nitrogen purge.

*The duration of the test is 48 hr; however, the test may be terminated early if excessive pressure generation is noted.*

A. The closed system shall be held at 71 (±3) °C [160 (±5) °F].

B. Pressure shall be recorded as a function of time.

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- C. At the end of the test, the immersion tubes shall be vented, removed from the water bath, and allowed to cool.
- D. The fluid shall be removed from the immersion tubes using inert atmosphere transfer and submitted for post-test analysis.
- E. The immersion tubes shall be removed from the system, inspected, rinsed with deionized water, and allowed to dry overnight.
- F. *Post-test fluid analyses are determined by the fluid being tested.*
  - 1. Post-test analyses for hydrazine fuels shall include assay or purity, carbon dioxide (CO<sub>2</sub>), and NVR.
  - 2. Nitrogen tetroxide and ammonia post-test analyses shall include NVR.

*In each case, the NVR may be analyzed for the appropriate metals (metallic specimen) or anions (nonmetallic specimen).*
- G. Post-test material analyses shall include photographic documentation, visual observations of the material using the standard terms (table 4), and determination of the mass and dimensions.
- H. Post-test material analyses for nitrogen tetroxide: DSC and FTIR shall be performed on the specimen after testing as a screen for the formation of potentially energetic materials produced by nitration.

### 7.15.10 Reporting

- a. The test report shall include specimen identification, method of preparation, configuration, fluid identity, test conditions, data, and observations from the test, including visual observations, photographs, gas evolution rate or system pressure with time, and results of post-test analyses.
- b. The test report (in the acceptable format) shall be submitted to MAPTIS.
- c. If there is a deviation from standard test conditions (test duration, temperature, or specimen surface area), the test shall be identified as nonstandard.

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### 7.15.11 Precision

Measurements shall be made to the following precision:

- a. Absolute Pressure:  $\pm 6.98$  kPa ( $\pm 0.5$  psi).
- b. Temperature:  $\pm 3$  °C ( $\pm 5.4$  °F).
- c. Specimen Dimensions:  $\pm 0.1$  mm ( $\pm 0.004$  in).
- d. Specimen Mass:  $\pm 1$  mg.
- e. Time:  $\pm 10$  sec.

### 7.15.12 Failure Criteria

*The criteria listed below are for failing. If the material does not fail, it still may not be appropriate for the proposed application without informed review of the data and/or additional long-exposure application and configuration-specific testing.*

The material shall be considered to have failed this test if any of the following occurs in either the screening test or the immersion test:

- a. Burning, charring, or fire.
- b. Frothing.
- c. The material dissolves in the test fluid.
- d. The material crumbles, becomes friable, or generates particulate.
- e. The material changes shape or physical form by more than 20 percent.
- f. The material suffers more than 20 percent degradation of the physical properties for which it was selected.
- g. Visible changes in appearance of the test fluid (color and/or clarity).
- h. For nitrogen tetroxide, a pressure rise  $> 68.9$  kPa ( $> 10$  psi).
- i. For polymers exposed to nitrogen tetroxide, evidence of material nitration as indicated by DSC and/or FTIR.

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*Pressure rise in the system is indicative of a chemical reaction, which will vary depending on the fluid. Ammonia and nitrogen tetroxide do not degrade catalytically, and a pressure rise is an indication of a chemical reaction. For the hydrazine family of fuels, the reaction is usually catalytic; the rate is dependant on the material and the surface area. No failure criteria for the gas evolution rate for the hydrazine fuels has been established because surface area of the use parts may be small, as in the case of O-rings or gaskets; however, the gas evolution data should be considered in the material selection.*

*In most cases, the generation of ionic species in solution, especially halides, can increase the potential for corrosion in a system. Generation of significant NVR or particulate has the potential of reducing flow in a system or interfering with close-tolerance moving parts, such as valves.*

### 7.15.13 Good Laboratory Practices

*Quality control is based on the pressure of the reference side of the system.*

Based on historical data, the pressure rise on the reference side of the system shall be <0.4 kPa (<0.06 psia)/hr for nitrogen tetroxide and ammonia; in the case of the hydrazine fuels, the gas evolution rate shall be <7.0 x 10<sup>-3</sup> standard cm<sup>3</sup>/(cm<sup>2</sup> hr).

### 7.16 Determination of Offgassed Products from Assembled Article (Test 16)

*Deleted in previous version.*

### 7.17 Upward Flammability of Materials in GOX (Test 17)

*VCS adopted and tailored.*

#### 7.17.1 Purpose

*The purpose of this test is to determine the flammability of materials at the use pressure in GOX at ambient or elevated temperatures. This test can be used to provide supplemental information by testing at pressures other than the intended use pressure.*

#### 7.17.2 Test Summary

a. Test 17 shall determine the flammability of materials at the use pressure in GOX at ambient or elevated temperatures.

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*Test 17 may be used to provide supplemental information by testing at pressures other than the intended use pressure.*

- b. The test specimens shall be 0.32-cm (0.126-in) diameter rods with a minimum length of 10.2 cm (4 in).
- c. The specimens shall be mounted vertically in a test chamber, ignited at the bottom by an ignition system, and allowed to burn until each self-extinguishes.
- d. The burn length, e.g., the length of the specimen that has been consumed by combustion, shall be measured.
- e. To determine a pressure at which the material is not flammable, at least 10 specimens shall be tested without consumption >3 cm (>1.2 in).

### 7.17.3 Test Criteria

*A material is considered flammable at the maximum use pressure if at least one specimen burns >3 cm (>1.2 in).*

- a. To determine a pressure at which the material is not flammable, at least 10 specimens shall be tested without consumption greater than >3 cm (>1.2 in).

*The results of this test are dependent upon the configuration of the test specimens. Specimens with high-surface-area-to-volume ratios, such as filter materials, burn at lower pressures than specimens in bulk configuration, such as 0.32-cm (0.126-in) rods.*

- b. The test shall be considered valid only if the promoter ignites, burns, and detaches from the specimen.

### 7.17.4 Test Method

The test method defined in ASTM G124-95, Standard Test Method for Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres, shall be followed for this test, with the following exceptions, clarifications, and additions.

*The relevant ASTM G124-95 section is included in parentheses.*

*ISO 14624-4, Space systems — Safety and compatibility of materials — Part 4: Determination of upward flammability of materials in pressurized gaseous oxygen or oxygen-enriched environments, describes a similar test procedure.*

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a. Exception (throughout): The specimen shall be tested at ambient temperature if its use temperature is  $\leq 260\text{ }^{\circ}\text{C}$  ( $\leq 500\text{ }^{\circ}\text{F}$ ).

b. Exception (throughout): If the specimen's use temperature is  $> 260\text{ }^{\circ}\text{C}$  ( $> 500\text{ }^{\circ}\text{F}$ ), the test specimen shall be preheated to the use temperature.

c. Addition (section 3): Burn length: The length of the specimen that has been consumed by combustion; determined by subtracting the sum of the post-test specimen length and the promoter length from the pre-test specimen length.

d. Addition (section 3): Flammable material: A material is considered to be flammable if it burns  $> 3\text{ cm}$  ( $> 1.2\text{ in}$ ).

e. Exception (section 8.2): For metallic materials, the promoter shall consist of a sufficient quantity of aluminum or magnesium to release at least  $3.0\text{ kJ}$  ( $717\text{ cal}$ ).

f. Exception (section 8.2): The power supply shall be capable of providing 40-ampere root-mean-squared at 50 volts direct current to supply current to an aluminum-palladium or nickel-chromium igniter wire.

g. Exception (section 8.2): For nonmetallic materials, the promoter shall be sufficient for ignition of the material, as determined by the responsible NASA Center's M&P organization.

h. Exception (section 10.1): The samples shall be a minimum of  $10.2\text{ cm}$  ( $4\text{ in}$ ) ( $\pm 5\text{ percent}$ ) in length.

*A minimum length of  $15\text{ cm}$  ( $6\text{ in}$ ) ( $\pm 5\text{ percent}$ ) is preferable.*

i. Exception (section 10.1): If a material cannot be obtained or prepared in the cylindrical form, a nonstandard specimen shall be prepared.

*The nonstandard specimen should have  $0.32\text{-cm}$  ( $0.126\text{-in}$ ) ( $\pm 5\text{ percent}$ ) sides and should be a minimum of  $10.2\text{ cm}$  ( $4\text{ in}$ ) ( $\pm 5\text{ percent}$ ) in length.*

j. Addition (section 16): The initial test temperature shall be recorded and have precision of  $\pm 5\text{ percent}$  of reading.

k. Addition (section 16): The test report (in the acceptable format) shall be submitted to MAPTIS.

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l. Addition (section 16): If there is a deviation from the standard test parameters, such as nonstandard specimen preparation, orientation, configuration, ignition source, or test pressure, the test shall be identified as nonstandard.

m. Addition (section 16.1.6): The pressure reading shall have a precision of  $\pm 1$  percent of reading.

n. Addition (section 16.1.8): The measurement of the length of sample consumed shall have a precision of  $\pm 0.25$  cm ( $\pm 0.1$  in).

o. Addition (section 16.1.8): The measurement of the length of sample consumed shall have a precision of  $\pm 0.25$  cm ( $\pm 0.1$  in).

### 7.18 Arc Tracking (Dry Arc Propagation Resistance) (Test 18)

#### 7.18.1 Purpose

*The purpose of this test is to provide an assessment of the ability of an insulation to prevent damage in an electrical arc environment. This test also evaluates the ability of the insulation to prevent further arc propagation when the electrical arc is re-energized.*

#### 7.18.2 Test Summary

*This test method evaluates the general arc propagation resistance characteristics of wire insulations. The test consists of connecting five wires of a seven-wire bundle to a specified power supply and installing the bundle in a test fixture to hold the wire bundle perpendicular to an abrader blade. The abrader blade is used to initiate an arc through oscillation. The extent of damage caused by arc propagation and the capability of wires to maintain their dielectric strength are evaluated.*

#### 7.18.3 Test Criteria

a. To determine the arc propagation resistance of the wire configuration, at least 15 seven-wire bundles shall be tested.

b. A wire insulation material shall be considered to have met the acceptance criteria of this test if:

(1) At least 64 wires shall pass the dielectric test.

(2) Three wires or less shall fail the dielectric test in any one bundle.

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- (3) Actual damage to the wire shall not be more than 7.6 cm (3 in) in any one bundle.

### 7.18.4 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Arc: A continuous, luminous discharge of electric current crossing a gap between two conducting surfaces.

Arc tracking (Arc propagation): That phenomena whereby an arc between two or more wires, once initiated, will sustain itself through a conductive path provided by degradation of the insulation for a measurable length.

### 7.18.5 Test Conditions

Test conditions shall be as defined in MIL-STD-2223, Test Methods for Insulated Electric Wire, Method 3007, Dry Arc Propagation Resistance, only, or as defined in SAE AS4373, Test Methods for Insulated Electrical Wire, Method 508, Dry Arc Propagation Resistance, only.

### 7.18.6 Specimen Preparation

a. A test specimen shall be a bundle of seven wires and of sufficient length [35.6 cm (14 in) minimum] to allow the bundle to be installed in the test fixture.

b. Fifteen bundles shall be required for a full test.

*For this test, 20 American Wire Gauge wire is recommended.*

c. The specimens shall be prepared according to MIL-STD-2223, Method 3007, or SAE AS4373, Method 508.

### 7.18.7 Test System

The test system shall be that described in MIL-STD-2223, Method 3007, or SAE AS4373, Method 508.

### 7.18.8 Pre-Test Procedure

The pre-test procedures shall be those described in MIL-STD-2223, Method 3007, or SAE AS4373, Method 508.

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### **7.18.9 Test Procedure**

The test procedures shall be those described in MIL-STD-2223, Method 3007, or SAE AS4373, Method 508.

### **7.18.10 Reporting**

a. The test report shall include specimen identification, test conditions, total number of wires that pass the dielectric test, number of wires from each bundle that pass the dielectric test, and the length of physical damage to each individual wire in the bundle.

b. The test report (in the appropriate format) shall be submitted to MAPTIS.

*For Test 18, test standards that meet or exceed the requirements of MIL-STD-2223, Method 3007, or SAE AS4373, Method 508, may be used with the approval of the responsible NASA Center's M&P organization.*

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### APPENDIX A

#### SUPPLEMENTAL TESTS

*Methods for tests designed to provide supplemental data are presented in this section.*

- a. Tests shall be performed by certified test facilities.
  - (1) The test facility shall demonstrate good laboratory practices to produce accurate and repeatable test data.
  - (2) Good laboratory practices shall include calibration and maintenance procedures.
  - (3) At least every 2 years, test facilities shall demonstrate testing proficiency to maintain certification in accordance with Appendix B.

b. Properly identified material for testing shall be provided by the responsible NASA Center or contractor hardware supplier and accompanied by a test request form similar to that provided in Appendix D.

*Alternatively, certified test facilities can be authorized by the test requester to procure the appropriate materials.*

- c. Material and Specimen Receipt and Preparation

- (1) Materials shall be accompanied by MSDSs to comply with materials-handling requirements defined by the Occupational Safety and Health Administration.
  - (2) Material specimens shall be visually inspected, and any flaws or contamination shall be noted in the test report.

*Materials 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, particulate, and handling. It is important that exposure of the material to these and other contamination sources be controlled sufficiently to minimize variation in test results.*

- (3) Specimens shall be prepared in the proper dimensions.

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- (4) Specimens shall be weighed and identified individually.
- (5) Specimens shall be cleaned to end-use specifications.
- (6) Specimens shall be inspected after preparation to ensure suitability for the specific test requested.
- (7) As a minimum, all fluids used for testing shall meet or exceed user specifications.

d. When there is a deviation from standard test parameters, such as nonstandard specimen preparation or test conditions, the test shall be identified as nonstandard.

*Table 3 lists the minimum quantities of material required to perform each test properly.*

### **A.1 Heat and Visible Smoke Release Rates (Test 2)**

#### **A.1.1 Purpose**

*The purpose of this test is to provide supplemental information on the flammability of materials.*

*This test is used to determine the heat evolved in, or contributing to, a fire involving products of the test material. The major information obtained includes effective heat of combustion, time to ignition, rate of heat released, smoke obscuration, and total heat released. Also, the test allows evaluation of the effective heat of combustion, mass loss rate, the time to sustained flaming, and smoke production.*

#### **A.1.2 Test Summary**

*This test method consists of exposing specimens in flowing ambient air or oxygen-enriched environments, while subjecting them to a predetermined external heat flux. Burning may be either with or without spark ignition. The measurements include oxygen concentrations, exhaust gas flow rate, mass-loss rate of the specimen, length of time to sustained flaming, and smoke obscuration. The rate of heat release is determined by measurement of the oxygen consumption; the effective heat of combustion is determined from a concomitant measurement of specimen mass-loss rate in combination with the heat release rate; and smoke development is measured by obscuration of light caused by the combustion product stream.*

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### A.1.3 Test Criteria

The test shall be conducted on specimens that are representative of those in the intended use environment and at worst-case conditions.

*There is no pass/fail criteria associated with this test; however, the test results may be used as elements of a fire risk assessment, which takes into account all the factors that are pertinent to an assessment of the fire hazard of a particular end use, such as scaling, surface morphology, and microgravity. The standard test is conducted under high flow rates of oxygen/nitrogen mixtures, which may not be representative of real spacecraft applications.*

### A.1.4 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Effective heat of combustion: The measured heat release divided by the mass loss for a specified time period.

Extinction coefficient: A measure of the reduction of light transmission through a medium.

Heat flux: The incident flux imposed externally from the radiant heater on the specimen.

Ignitability: The propensity of a material to ignite as measured by the time to ignition at a specified heating flux.

Rate of heat release: The heat evolved from the specimen per unit time.

Smoke obscuration: The reduction of light transmission by smoke, as measured by light attenuation, and reported as the extinction coefficient.

Total heat release: The quantity of heat released determined by integrating the rate of heat released as a function of time.

### A.1.5 Test Conditions

Test conditions (incident heat flux and oxygen concentration) shall simulate the worst-case conditions in which ignition and combustion of the material are most likely to occur.

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### A.1.6 Specimen Preparation

a. Specimens shall be prepared in accordance with ASTM E1354, Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter.

b. Coatings or any viscous materials that cannot be mounted for testing without a substrate shall be applied to the end-use substrate material in the worst-case thickness.

*Aluminum foil substrates, approximately 0.08 mm (0.003 in) thick, can be used if the end-use substrate is not known or appropriate.*

c. Cleaning of Specimens

- (1) Contamination on the surfaces of solid, nonporous specimens shall be removed by washing with deionized water and mild detergent, rinsing with deionized water, and drying with filtered gaseous nitrogen (GN<sub>2</sub>).
- (2) Particulate on the surfaces of solid, porous specimens shall be removed with filtered GN<sub>2</sub>.

### A.1.7 Test System

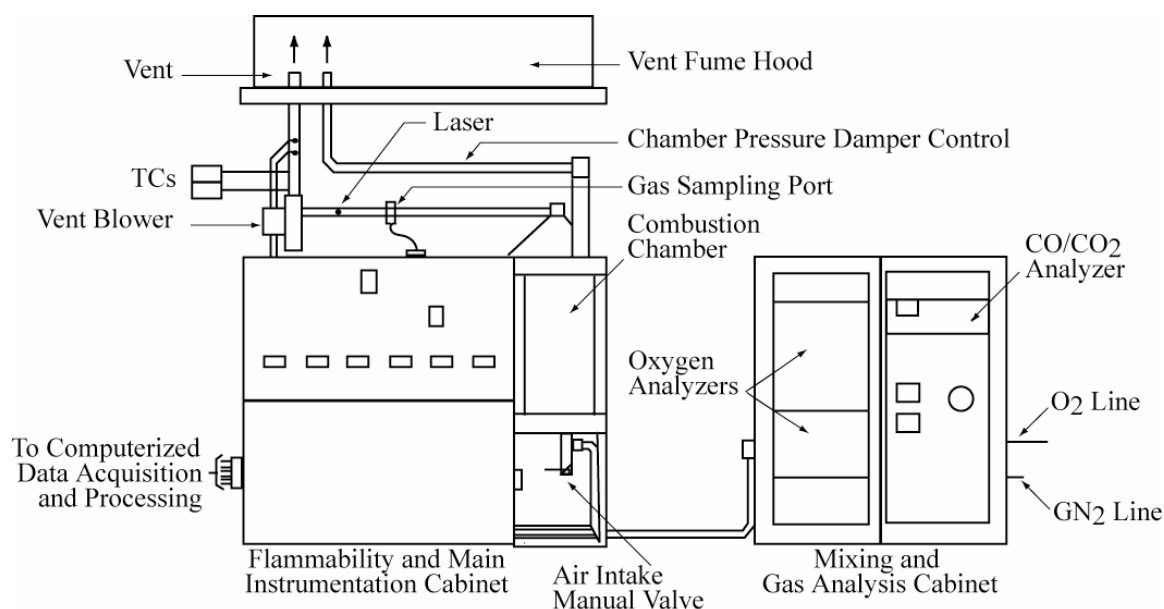
The test system shall be as described in ASTM E1354 but with additional capabilities that will allow testing in oxygen/nitrogen mixtures other than air.

*A typical test system is shown in figure 4.*

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**Figure 4—Test System for Test 2**

### A.1.8 Pre-Test Procedure

The pre-test procedures shall be as described in ASTM E1354.

### A.1.9 Test Procedure

The test procedures shall be as described in ASTM E1354, with the following exceptions:

- a. The specimen shall be placed on the load cell in the test chamber and exposed to the proper test atmosphere by allowing the test gases to flow through the test chamber.
- b. The initial oxygen concentration shall be measured.

### A.1.10 Reporting

The test report shall include specimen identification, configuration, test conditions, applied heat flux, time to ignition, maximum and average rate of heat released, total heat released, specimen mass loss, smoke obscuration (extinction coefficient), and other observations from the test.

*Proper reporting of the test observations is critical.*

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### A.2 Flash Point of Liquids (Test 3)

#### A.2.1 Purpose

*The purpose of this test is to provide supplemental information on the flash point of liquids.*

#### A.2.2 Test Summary

*The test method for determining the Flash Point of Liquids consists of placing a specimen in a specimen cup and heating it at a controlled rate, with or without stirring. A small flame is directed into the vapor space of the cup at regular intervals to determine whether a flash occurs.*

#### A.2.3 Test Criteria

*a. This test is used to determine the flash point of liquids under specified conditions of test; therefore, test criteria are dependent upon the intended use of the material.*

*b. The flash point temperature is a measure of the tendency of the test specimen to form a flammable mixture with air under controlled laboratory conditions. It is only one of a number of properties that must be considered in assessing the overall flammability hazard of a material.*

#### A.2.4 Definitions

*The definition of the relevant term used in the description of this test method is:*

Flash point. The lowest temperature, corrected to a barometric pressure of 101.3 kPa (14.7 psia) at which application of an ignition source causes the vapors of a specimen of the specimen to ignite under specified conditions of test.

#### A.2.5 Selection of a Flash Point Test Method

The appropriate flash point test method for the application shall be selected by following the recommendations of ASTM E502-07, Standard Test Method for Selection and Use of ASTM Standards for the Determination of Flash Point of Chemicals by Closed Cup Methods.

*a. Depending on the application, an open-cup method such as ASTM D92-05, Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester, or ASTM*

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*D1310-01, Standard Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus, also may be used.*

*b. Some pure materials, such as trichloroethylene, require large diameters for flame propagation. While these materials do not propagate a flame in an apparatus the size of a flash-point tester, their vapors are flammable and burn when ignited in an apparatus of adequate size.*

### A.2.6 Test Systems and Procedures

The test systems and procedures shall be identical to those described in the selected ASTM test method(s).

### A.2.7 Reporting

The test report shall include specimen identification, the method used, test conditions, the flash point of the liquid corrected to 101.3 kPa (14.7 psia), and observations from the test.

### A.2.8 Precision

Measurements shall meet the precision requirements of the ASTM method(s) used.

## A.3 Odor Assessment (Test 6)

### A.3.1 Purpose

*The purpose of this test is to determine if the odor from a material or assembled article is objectionable or revolting.*

### A.3.2 Test Criteria

*The odor from a material or assembled article is objectionable or revolting if an average rating of 2.5 or higher (on an odor-characteristic scale of 4) is assigned from the test.*

### A.3.3 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Assembled article: An assembled article could be any component or assembly of components that is not a single material.

Objectionable odor: An odor that is disagreeable.

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Offgassed product: An organic or inorganic compound evolved as a gas from a material or assembled article.

Offgassing: The evolution of gaseous products from a liquid or solid material into an atmosphere.

Revolting odor: An odor that is extremely offensive and causes discomfort.

Ambient (room) temperature: Room temperature is 23 ( $\pm 5$ ) °C [73 ( $\pm 9$ ) °F].

### A.3.4 Test Conditions

a. The test atmosphere shall be at least a volume fraction of 20.9 ( $\pm 2$ ) percent for oxygen, with the balance being nitrogen or argon.

b. Test pressure shall be  $\pm 3.5$  kPa ( $\pm 0.5$  psi) of the ambient pressure at the test facility.

c. The maximum volume fraction limits (expressed as a volume fraction in  $\mu\text{l/l}$ ) for impurities in the compressed gases shall be:

(1) Carbon monoxide: 1.0.

(2) Carbon dioxide: 3.0.

(3) Total hydrocarbons, as methane: 0.1.

(4) Halogenated compounds: 0.5.

(5) Water: 7.0.

*Batteries or assembled articles containing batteries should be tested in an inert atmosphere to reduce the risk of generating an explosive gas mixture. The batteries or assembled articles containing batteries tested in an inert atmosphere do not need to be tested again in an oxygen atmosphere for toxic offgassing.*

d. The specimen shall be subject to a thermal exposure for 72 ( $\pm 1$ ) hr at 50 ( $\pm 3$ ) °C [122 ( $\pm 5$ ) °F].

*Specimens tested at one oxygen concentration do not have to be retested at a different oxygen concentration.*

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### A.3.5 Specimen Preparation

- a. Test specimens shall be prepared from either materials or assembled articles.
- b. Handling of test specimens shall be in a manner that preserves the integrity of the specimen surface without adding contaminants.
- c. All materials shall meet the requirement of test-material-mass-to-specimen-container-volume ratio of 5.0 ( $\pm 0.25$ ) g/l. The approximate total specimen surface area shall be recorded.
- d. Preparation of Specimens to Proper Dimensions

#### (1) Specimen Preparation for Test Materials Based on Mass

- A. Materials that are essentially two-dimensional and require application to a substrate, e.g., coatings, primers, inks, paints, adhesives, tapes, and thin film lubricants, shall be applied at their thickness of use to clean aluminum substrates. A sufficient number of substrates with applied specimen material shall be prepared to provide a net test-material-mass-to-specimen-container-volume ratio of 5.0 ( $\pm 0.25$ ) g/l. The approximate total specimen surface area shall be recorded.

*Specimens may be applied to both sides of the substrate.*

- B. Materials that are essentially two-dimensional and are not applied to a substrate, e.g., fabrics, photographic film plastic, plastic film, elastometrics, and non-adhesive tape, shall be cut to convenient test dimensions. Heat-shrinkable tubing shall be shrunk to simulate actual use configuration. A sufficient quantity of specimens shall be prepared to provide a test-material-mass-to-specimen-container-volume ratio of 5.0 ( $\pm 0.25$ ) g/l. Liquids shall be placed in suitable non-reactive vessels. The approximate total specimen surface area shall be reported.
- C. Specialized items and materials that do not meet the above requirements and that require special handling, most often non-homogeneous materials, shall be tested in the manner designated by the responsible NASA Center's M&P organization. The manner of testing and specimen preparation shall be reported.

*The desired test-material-mass-to-specimen-container-volume ratio for such materials is 5.0 ( $\pm 0.25$ ) g/l.*

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### (2) Specimen Preparation for Flight Articles

- A. Specimens that are assembled articles shall be inspected for parts that are not designated for flight, e.g., dust covers, tape, or test leads. These items shall be removed before testing. The absence of items, e.g., batteries or photographic film, that will be included during flight but that are not included with the specimen shall be recorded.
- B. The ratio of test-material-mass-to-specimen-container-volume shall be approximately 1:3.

*When flight articles are required for other activities and have to be unloaded before the Test 7 results can be evaluated for toxicity, the offgas test atmosphere can be transferred to another specimen container and preserved for odor assessment.*

- C. The authority having jurisdiction shall determine the specific requirements for the preservation of the offgas test atmosphere.
- D. The odor assessment shall be initiated within 14 days from the start of the specimen gas preservation.

e. Cleaning of Specimens. Specimens shall be cleaned if specified by the requester.

- (1) Specimens shall be cleaned and dried to the end-use specifications by the requester before receipt at the test facility.
- (2) The cleaning of assembled articles shall be the responsibility of the test requester.
- (3) If a specimen received by the test facility is visibly contaminated, clear instructions shall be received from the requester as to proper procedures for continuing testing.
- (4) For specimens prepared by the test facility, all preparation and cleaning shall be in accordance with user/requester specifications.
- (5) All cleaning procedures shall be first approved by the facility and verified to have no influence on analytical results.

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*As a minimum, particulate on specimen surfaces should be removed with filtered GN<sub>2</sub>.*

### A.3.6 Test System

- a. The test system shall consist of the specimen container, the test chamber with controlled temperature, and volunteer odor panel personnel.
- b. The specimen container shall be easy to clean and constructed so that gas specimens can be collected easily. The specimen container, including any soft goods, shall not affect significantly the concentration of products offgassed from the specimens.
- c. The test chamber shall have the capability to maintain the test temperature to within  $\pm 3$  °C ( $\pm 5.4$  °F) for the duration of the test. The test chamber instrumentation shall have the capability to record the temperature continuously.
- d. Glass syringes [30 cm<sup>3</sup> (1.8 in<sup>3</sup>) capacity] shall be used for measuring and administering the odor specimen. When administering the specimen, a low-odor non-obtrusive mask that covers the nose and mouth shall be used. Neither the syringes nor the masks shall affect the results of the tests measurably.

### A.3.7 Pre-Test Procedure

- a. A NASA or NASA contractor volunteer shall perform the following:
  - (1) Sign a consent form as required in NPR 7100.1, Protection of Human Research Subjects, and NPD 7100.8, Protection of Human Research Subjects.
  - (2) Be examined and qualified medically.
  - (3) Be odor qualified by distinguishing the seven primary standards (table 5) from three odorless standards.

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**Table 5—Seven Primary Standards for Detection of Odor\***

ODOR	STANDARD COMPOUND	DILUTION IN WATER
Ether	Diethyl ether	90 ml in 333 ml
Camphor	1, 8-Cineole	5 ml in 500 ml
Musk	15-Hydroxypentadecanoic acid lactone	1 mg in 1000 ml
Floral	1-Methyl-1-ethyl-2-phenylpropanol	75 ml in 500 ml
Mint	dl-Menthone	2 ml in 333 ml
Pungent	Acetic acid	2 ml in 333 ml
Putrid	Methyl disulfide	1 ml in 10 l

\*The Test 6 convention is to express primary standards for detection of odor in metric units only.

- b. An odor panel shall test each new compressed gas that is used for test atmospheres before use. Gasses used for test atmospheres shall be judged as being odorless.
- c. The specimen containers shall be cleaned by washing with a diluted soap solution and rinsing with deionized water. They shall be allowed to dry and then purged with air or nitrogen. Before use, each container shall be certified to be free of odor.
- d. Before odor testing, materials or assembled articles shall be tested for offgassed products (Test 7).
- e. If the gas from the specimen container has been determined to be unsafe to test, based on the offgassing analysis, the calculated toxic level and reasons for not performing the test shall be recorded.
- f. Duplicate specimens of materials shall be offgassed—one specimen for offgassing analysis and the other for odor assessment. If the specimen cannot be provided in duplicate, the same specimen shall be used in both offgassing analysis and odor assessment.
- g. Before each test, members of the odor panel shall receive a nose and throat examination (for nasal irritation or other abnormal conditions) by a medical staff member. Results of this examination shall be recorded.
- h. Each odor panel member shall identify an odorless solution from two of the seven primary standards. Members of the odor panel shall not be allowed to participate if their sense of smell has been affected in any manner, such as by recent smoking, ingestion of highly flavored foods, or exposure to pungent vapors.

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### A.3.8 Test Procedure

- a. The specimen shall be weighed and placed in the specimen container.
- b. The room atmosphere in the specimen container shall be replaced with the test atmosphere, either by purging or by evacuation. The requesting organization shall indicate if the specimen can or cannot withstand a vacuum; exposure of any specimen to vacuum shall be less than 3 min.
- c. The specimen container, with the test atmosphere, shall be at the requested test pressure when the test temperature is achieved.
- d. The specimen shall be placed in the test chamber and heated to the test temperature of  $50 (\pm 3) ^\circ\text{C}$  [ $122 (\pm 5) ^\circ\text{F}$ ], unless otherwise specified. This temperature shall be maintained for  $72 (\pm 1)$  hr. Then, the specimen container shall be cooled to ambient temperature, and the pressure shall be recorded.
- e. The odor panel shall be convened, and at least five qualified members shall be administered at least  $30 \text{ cm}^3$  of the gas from the specimen container. Using the following scale, each odor panel member shall assign an odor characteristic to the gas from the specimen container.

Undetectable:	0
Barely Detectable:	1
Easily Detectable:	2
Objectionable:	3
Revoltant:	4
- f. Between 2 and 4 hr after the test, the panel members shall be examined medically for nasal irritation or other abnormal conditions. The results of this examination shall be recorded.
- g. Each odor panel member shall be exposed to only one odor specimen in 48 hr.

### A.3.9 Reporting

- a. The test report shall include specimen identification, configuration, test conditions, and the average rating from the odor panel members.
- b. Any significant results from the medical examination shall be recorded.

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c. If the material is determined to be unsafe for testing (based on the offgassing analysis from Test 7), the reasons for the determination not to perform Test 6 on the specimen shall be included.

d. The test report (in the acceptable format) shall be submitted to MAPTIS.

### A.3.10 Precision

Measurements shall be made to the following precision:

- a. Absolute pressure:  $\pm 1$  percent of reading.
- b. Temperature:  $\pm 3$  °C ( $\pm 5.4$  °F).
- c. Oxygen concentration:  $\pm 0.5$  percent of reading.
- d. Mass:  $\pm 0.01$  g.

### A.3.11 Good Laboratory Practices

Each odor panel member shall be requalified every 4 months, using the procedure described in section A.3.7a.

## A.4 Configurational Flammability (Test 10)

*This test was formerly titled Simulated Panel or Major Assembly Flammability Test. In situations in which materials do not meet the criteria of Test 1, Test 10 may be used to gather supplemental data.*

### A.4.1 Purpose

*The purpose of this test is to determine if a hardware article, when exposed to a standard ignition source, will self-extinguish and not transfer burning debris, which can ignite adjacent materials or other hardware.*

### A.4.2 Test Criteria

Test 10 shall be performed in accordance with the test procedure described in Test 1.

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### A.4.3 Test Method

a. A test plan specific for the worst-case use environment (maximum temperature, pressure, and oxygen concentration), placement of ignition source, use configuration, and application shall be developed by the test facility in conjunction with the test requester.

b. The acceptance criteria shall be determined by the responsible NASA Center's M&P organization.

### A.5 Mechanical Impact for Materials in Ambient Pressure LOX (Test 13A) and Mechanical Impact for Materials in Variable Pressure GOX and LOX (Test 13B)

#### A.5.1 Purpose

*This test provides supplemental information on the reaction sensitivity of materials to ignition by mechanical impact in GOX or LOX. The test can be performed to meet any of the following objectives:*

- a. To characterize the reaction sensitivity of a material at a certain impact energy.*
- b. To determine the impact energy threshold of a material at a given pressure.*
- c. To determine the pressure threshold of a material at a given impact energy.*

#### A.5.2 Test Summary

- a. The test specimens shall be 17.5 mm (0.69 in) in diameter and 1.52 mm (0.060 in) thick.
- b. The specimens shall be subjected to mechanical impact at the desired energy and inspected for evidence of a reaction.
- c. Typical test criterion: When impacted at 98 J (72 ft-lb), 20 specimens shall not react.
- d. If 1 specimen out of 20 reacts, 40 additional specimens shall be tested without any reactions.

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### A.5.3 Test Criteria

*This test evaluates the reaction sensitivity of materials when mechanically impacted in oxygen; therefore, the test criteria are dependent on the application.*

- a. When impacted at 98 J (72 ft-lb), 20 specimens shall not react (typical criterion).
- b. If 1 specimen out of 20 reacts, 40 additional specimens shall be tested without any reactions.

### A.5.4 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Mechanical impact: Energy delivered by a plummet that has been dropped from a pre-established height onto a striker pin in contact with a specimen.

Reaction: A chemical change or transformation in the specimen caused by a mechanical impact. A reaction from mechanical impact can be determined by an audible report, an electronically or visually detected flash, or obvious charring of the specimen, specimen cup, or striker pin.

### A.5.5 Test Conditions

*The thickness of the specimen should be the worst-case thickness.*

- a. For ambient pressure LOX tests, the test conditions (pressure and temperature) shall be the ambient pressure of the test facility and the boiling point of LOX at that pressure.
- b. For variable pressure LOX and GOX tests, the test conditions (pressure and temperature) shall be determined for each test as recommended in the OCA.

### A.5.6 Specimen Preparation

- a. Materials shall be prepared as stated in ASTM G86-98, Standard Test Method for Determining Ignition Sensitivity of Materials to Mechanical Impact in Ambient Liquid Oxygen and Pressurized Liquid and Gaseous Oxygen Environments.
- b. The test material dimensions specified in ASTM G86-98 shall be used, unless otherwise specified by the responsible NASA Center's M&P organization.

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*As a minimum, unless otherwise specified or approved by the NASA Center's M&P organization, contamination on the surfaces of solid, nonporous specimens should be removed by washing with deionized water and mild detergent, rinsing with deionized water, and drying with filtered GN<sub>2</sub>.*

*Particulates on the surfaces of solid, porous specimens should be removed with filtered GN<sub>2</sub>.*

c. The specimen shall be inspected, and flaws shall be noted. If the flaws result from specimen preparation at the test facility, new specimens shall be prepared.

d. When testing materials to determine relative ranking, specimen preparation (including cleaning) and condition, e.g., thickness and surface finish, shall be identical.

### A.5.7 Test System

The test system shall be identical to that described in ASTM G86-98.

### A.5.8 Pre-Test Procedure

The pre-test procedure, including calibration of the test system, shall be identical to that described in ASTM G86-98.

### A.5.9 Test Procedure

The test procedure shall be identical to that described in ASTM G86-98, with the exception that testing shall be performed at the requester-specified pressure, temperature, and impact energy.

### A.5.10 Reporting

a. The test report shall include specimen identification, configuration, test conditions, number of reactions, and observations from the test.

*Proper reporting of the test observations, especially of unusual behavior, is critical.*

b. The test report (in the acceptable format) shall be submitted to MAPTIS.

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### A.5.11 Precision

Precision of measurements, such as specimen dimensions, drop height, and time, shall be identical to those described in ASTM G86-98.

### A.6 Gaseous Fluid Impact for Components

#### A.6.1 Purpose

*This test provides supplemental information on the reaction sensitivity of components to rapid pressurization heating when pneumatically impacted in a pressurized GOX system. The test can be performed to meet any of the following objectives:*

- a. To characterize the reaction sensitivity of a component at a certain pressure.*
- b. To determine the pressure threshold for ignition of a component over a range of pressures.*
- c. To determine the temperature reaction threshold of a component at a certain pressure.*

#### A.6.2 Test Summary

- a. The test specimens shall be components in their normal use condition, including the end-use cleanliness level.
- b. The test specimens shall be subjected to gaseous fluid impact at 1.25 times Maximum Operating Pressure (MOP), followed by functional tests and inspection for evidence of ignition.
- c. At least one component shall be subjected to a minimum of 60 pneumatic impacts.

#### A.6.3 Test Criteria

*This test evaluates the reaction sensitivity of components when pneumatically impacted in a pressurized GOX system; therefore, the test criteria are dependent on the application.*

- a. At least one component shall be subjected to a minimum of 60 pneumatic impacts.
- b. Pressurization shall be through the ports specified by an OCA.

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*Testing of up to three components is preferable.*

### A.6.4 Definitions

*The definition of the relevant term used in the description of this test method is:*

Gaseous fluid impact: Heat delivered to a specimen by rapid fluid compression; may also be referred to as pneumatic impact, rapid pressurization, or adiabatic compression.

### A.6.5 Test Conditions

- a. Test pressure shall be 1.25 times MOP.
- b. Test gas temperature shall be 60 ( $\pm 3$ ) °C [140 ( $\pm 5.4$ ) °F].
- c. Pressurization rate to within 95 percent of the test pressure shall be 20 (+0/-5) msec to enhance reaction probability in the component.

### A.6.6 Specimen Preparation

Components shall be tested in their normal use condition, including the end-use cleanliness level.

### A.6.7 Test System

The test system shall be as described in ASTM G74-01, Standard Test Method for Ignition Sensitivity of Materials to Gaseous Fluid Impact, with the exception that the test chamber subassembly shall be replaced by the component to be tested.

### A.6.8 Test Procedure

The test procedure for testing components shall be as described in ASTM G74-01 with the following exceptions:

- a. The test chamber subassembly shall be replaced with the component to be tested.
- b. The configuration of the component to be tested shall be as recommended in the OCA.

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c. The component shall be subjected to impacts at intervals of approximately 30 sec in each test configuration recommended in the OCA.

d. After testing, each component shall be subjected to functional tests and inspected for signs of ignition.

### A.6.9 Reporting

The test report shall include specimen identification, configuration, test conditions, number of reactions, and observations from the test.

*Proper reporting of the test observations, especially of unusual behavior, is critical.*

### A.6.10 Precision

Measurements shall be made to the following precision:

- a. Absolute pressure:  $\pm 1$  percent of reading.
- b. Temperature:  $\pm 3$  °C ( $\pm 5.4$  °F).

## A.7 Reactivity and Penetration of Materials due to Incidental Exposure to Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia

### A.7.1 Purpose

*The purpose of this test is to identify changes resulting from incidental exposure (minor amounts, such as a splash) to fluids that degrade or penetrate the material or produce a reaction.*

### A.7.2 Test Criteria

*This test is used to determine and document the effects of the hydrazine family of fuels, nitrogen tetroxide and mixed oxides of nitrogen, and ammonia on materials; therefore, any test criteria are dependent on the intended use of the material.*

*The acceptability of the material is determined by the test requester and the responsible NASA Center's M&P organization.*

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### A.7.3 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Degradation: An adverse physical or chemical change in a substance.

Reaction: A chemical change in which a substance decomposes, combines with other substances, or interchanges constituents with other substances.

### A.7.4 Test Conditions

a. Unless otherwise specified, the test conditions shall be the ambient temperature and pressure of the test facility.

*Incidental exposure time is considered to be  $\leq 240$  min.*

*Test exposure time is specified by the requester, based on the intended use for the material and expected duration of field exposure.*

*In the case of gross reactivity, the test may be terminated early.*

#### b. Test Fluids

- (1) Hydrazine shall meet the requirements of MIL-PRF-26536.
- (2) UDMH shall meet the requirements of MIL-PRF-25604.
- (3) MMH shall meet the requirements of MIL-PRF-27404.
- (4) A-50 shall meet the requirements of MIL-PRF-27402.
- (5) Nitrogen tetroxide and mixed oxides of nitrogen shall meet the requirements of MIL-PRF-26539.
- (6) Ammonia shall be procured with a stated purity of 99.99 percent (liquid phase).

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### **A.7.5 Specimen Preparation**

#### **A.7.5.1 Films, Fabrics, Sheets, Metals, and Composites**

*Preparation of these specimens for testing involves the following tasks:*

- a. Preparation of a specimen of the proper mass or dimensions. Specimens shall be prepared to a geometric surface area of 10.2 by 10.2 cm (4 by 4 in).
- b. Specimens shall be cleaned and dried to end-use specifications.

#### **A.7.5.2 Adhesives and Coatings**

Adhesives and coatings shall be applied in a thickness equivalent to normal use on aluminum foil or 304L stainless steel substrate and cured, if necessary, in accordance with the manufacturer's instructions.

#### **A.7.5.3 Tapes**

Tapes shall be applied on aluminum foil or 304L stainless steel substrate, a watch glass, or a glass petri dish in the as-received condition and thickness.

#### **A.7.5.4 Greases and Gels**

Greases and gels shall be applied on aluminum foil or 304L stainless steel substrate in a thickness equivalent to the normal use and cured, if required, in accordance with the manufacturer's instructions.

#### **A.7.5.5 Complex Shapes**

Complex shapes, such as O-rings, cables, and pipes, shall be tested in a cleanliness configuration consistent with the intended use.

### **A.7.6 Test System**

*This test requires handling hazardous fluids and has the potential to produce energetic events such as fire, thermal runaway, or explosion.*

- a. Testing shall be carried out with the appropriate engineering controls and protective equipment.

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b. The test system for the reactivity and penetration test for films, fabrics, sheets, metals, and composites shall consist of a glass beaker in a fume hood approved for the handling of the test fluid.

c. The test system for the reactivity test for all other materials shall consist of a watch glass or glass petri dish in a fume hood approved for the handling of the test fluid.

### A.7.7 Pre-Test Procedure

a. The fluid to be used in testing shall be analyzed and verified to meet the required use specifications before use.

b. All pertinent information for the test. e.g., specimen identification, composition, pre-test mass and dimensions, and fluid analysis results, shall be recorded.

c. Reference/pre-test photos of the specimens shall be taken.

d. The test system shall be clean, and all the measuring devices shall be in current calibration.

e. As a precaution, initial exposure test of the specimen material shall be conducted in accordance with the screening test procedure of Test 15.

### A.7.8 Test Procedure

#### A.7.8.1 Reactivity and Penetration of Films, Fabrics, Sheets, Metals, and Composites

a. The test material specimen shall be placed over a beaker.

b. The test fluid shall be added drop by drop, slowly at first, and observed for any evidence of gross reactivity.

c. If no gross reactivity is observed, the remainder of the test fluid (typically 1 ml total) shall be added to the center of the specimen, without exposing the edges of the specimen to the fluid.

*The test convention is to express test specimen weight and volume in metric units only.*

*During specimen preparation, consideration should be given to edge effects of the specimen, e.g., cut ends of composite structures, insufficient application of coatings.*

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*Specimens are prepared to a geometric surface area; however, actual surface area may be greater.*

d. The test fluid shall be allowed to stand on the specimen for the specified exposure time.

*Test fluid should be added as required to maintain a liquid film on the test specimen during the exposure time.*

e. The specimen shall be observed for visible signs of reaction (table 4), such as burning, smoking, frothing, charring, solubility, swelling, fracture, or penetration of the specimen throughout the test.

*The test may be stopped at signs of gross reactivity.*

f. After testing, each component shall be subjected to functional tests and inspected for signs of degradation.

g. The time of the first instance of penetration (first drop of liquid in the beaker) shall be recorded. For materials used for protective garments, the time of initial appearance of wetness on the underside of the test specimen shall be recorded.

*Atmospheric condensation could form on the underside of the test specimen, giving a false indication of penetration; verification of penetration should be made by applying a blotter that changes color in the presence of the test fluid.*

### **A.7.8.2 Reactivity of All Other Materials**

a. The specimen shall be placed on a watch glass or glass petri dish.

b. The test fluid shall be added drop by drop, slowly at first, and shall be observed for any evidence of gross reactivity.

c. If no gross reactivity is observed, the remainder of the test fluid (typically 1 ml total) shall be added to the center of the specimen, without exposing the edges of the specimen to the fluid.

d. The test fluid shall be allowed to stand on the specimen for the specified exposure time.

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*Test fluid should be added as required to maintain a liquid film on the test specimen during the exposure time.*

e. The specimen shall be observed for visible signs of reaction (table 4), such as burning, smoking, frothing, charring, solubility, swelling, fracture, or penetration of the specimen throughout the test.

f. At the end of the specified exposure time, the liquid shall be blotted from the specimen.

*The specimen should be rinsed with running water for 60 sec.*

g. The test specimen shall be allowed to air dry for 24 hr before final evaluation.

h. Greases or uncured materials shall not be rinsed or blotted. Any excess test liquid shall be poured off.

i. The test specimen shall be allowed to stand in air for 24 hr before final evaluation.

### **A.7.8.3 Post-Test Material Analysis**

Post-test material analysis shall include photographic documentation, visual observations of the material using a set of defined standard terms, and determination of the mass and dimensions when possible.

*Table 4 (section 7.15.9) lists the defined standard terms.*

### **A.7.9 Reporting**

a. The test report shall include specimen identification, configuration, fluid identity, test conditions, and observations from the test.

b. Any reactivity observed during the exposure, such as burning, smoking, frothing, charring, solubility, swelling, or fracture of the specimen, shall be recorded in the report.

c. For penetration, the elapsed time at the first instance of penetration (or appearance of wetness for protective garments) shall be reported.

d. Relevant post-test analysis results for the material shall be included.

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- e. Post-test photographs shall be included, as required, to document condition of the material.
- f. The test report shall be submitted to MAPTIS.

### A.7.10 Precision

Measurements shall be made to the following precision:

- a. Absolute pressure:  $\pm 3.4$  kPa ( $\pm 0.49$  psi).
- b. Temperature:  $\pm 3$  °C ( $\pm 5.4$  °F).
- c. Specimen dimensions:  $\pm 0.1$  mm ( $\pm 0.004$  in).
- d. Specimen mass:  $\pm 1$  mg.

## A.8 Autogenous Ignition Temperature

### A.8.1 Purpose

*The purpose of this test is to provide information on the temperature at which liquids or solids will ignite spontaneously.*

### A.8.2 Test Summary

*The autogenous ignition temperature test consists of exposing a material in a reaction vessel to a pressurized environment containing 0.5 percent to 100 percent oxygen and heating at a predetermined rate. The minimum temperature required to cause the specimen to ignite spontaneously is denoted by a sudden temperature rise and is considered the autogenous ignition temperature.*

### A.8.3 Test Criteria

*This test is used to determine the autogenous ignition temperature (commonly called the autoignition temperature) under specified conditions of the test; therefore, any test criteria are dependent upon the intended use of the material, as evaluated through hazards analyses through engineering assessments for safe system operations.*

*This procedure provides a numerical value for the temperature at the onset of ignition under carefully controlled conditions. This is only one of a number of properties to be considered in assessing the overall ignitibility hazard of a material.*

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### **A.8.4 Definitions**

*The definition of the relevant term used in the description of this test method is:*

Autoignition temperature: The lowest temperature at which a material will spontaneously ignite under specific test conditions.

### **A.8.5 Test Conditions**

The test conditions shall be identical to those described in ASTM G72-01, Standard Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment.

### **A.8.6 Specimen Preparation**

Specimen preparation shall be as described in ASTM G72-01.

### **A.8.7 Test System**

The test system shall be identical to that described in ASTM G72-01.

### **A.8.8 Pre-test Procedures**

The pre-test procedures shall be identical to those described in ASTM G72-01.

### **A.8.9 Test Procedures**

- a. The test procedures shall be identical to those described in ASTM G72-01.
- b. At least five specimens shall be tested under each test condition.

### **A.8.10 Reporting**

- a. The test report shall include specimen identification, the method used, test conditions, ignition temperature, temperature rise on ignition, and observations from the test.
- b. The test report shall be submitted to MAPTIS.

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### A.8.11 Precision

Measurements shall meet the ASTM G72-01 precision requirements.

## A.9 Heat of Combustion

### A.9.1 Purpose

*The purpose of this test is to provide information on the heat evolved per unit mass when a nonmetallic material is completely burned in oxygen.*

### A.9.2 Test Summary

*Heat of combustion is determined by burning a weighed specimen in an oxygen environment in a bomb calorimeter under controlled conditions. The heat of combustion is calculated from temperature measurements before, during, and after combustion.*

### A.9.3 Test Criteria

- a. This test is used to determine the heat of combustion of nonmetals.*
- b. Any test criteria are dependent upon the intended use of the material, as evaluated through hazards analyses by engineering assessments to ensure safe systems operations.*
- c. The heat of combustion is only one of a number of properties to be considered in assessing the overall oxygen compatibility of a material.*

### A.9.4 Definitions

*Definitions of relevant terms used in the description of this test method are:*

Gross heat of combustion: The quantity of heat released when a unit mass of fuel is burned in a constant volume enclosure, with the products being gaseous, other than water that is condensed to the liquid state.

Net heat of combustion: The quantity of heat released when a unit mass of fuel is burned at constant pressure, with all of the products, including water, being gaseous.

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### A.9.5 Test Conditions

The test conditions shall be identical to those described in ASTM D240–02, Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter, or in ASTM D4809–06, Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (High Precision Method).

### A.9.6 Specimen Preparation

The specimen preparation shall be identical to the procedures described in ASTM D240–02 or ASTM D4809–06.

### A.9.7 Test System

The test system shall be identical to that described in ASTM D240–02 or ASTM D4809–06.

### A.9.6 Test Procedures

a. The test procedures shall be identical to those described in ASTM D240–02 or ASTM D4809–06.

b. At least five specimens shall be tested under each test condition.

*The gross heat of combustion is determined experimentally; however, the net heat of combustion is the quantity more commonly used. The gross heat of combustion for polymers of interest for aerospace applications (especially oxygen systems) is conservative when compared with the net heat of combustion by ~0.6 MJ/kg (~150 cal/g) or less. The gross heat of combustion is adequate for evaluating materials compatibility for oxygen compatibility applications.*

### A.9.7 Reporting

a. The test report shall include specimen identification, the method used, test conditions, gross heat of combustion, and observations from the test.

b. The test report shall be submitted to MAPTIS.

### A.9.8 Precision

Measurements shall meet the ASTM D240–02 or ASTM D4809–06 precision requirements.

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### A.10 Oxygen Index (ASTM G125-00)

*As part of pre-selection of previously untested nonmetallic materials for oxygen service, nonmetallic materials may be tested according to ASTM G125-00, Standard Test Method for Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants, or ASTM D2863-06, Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index).*

### A.11 Electrical Arc Test

#### A.11.1 Purpose

*Electrical arc tests are designed to determine the voltage and current needed to produce ignition in nonmetallic materials.*

#### A.11.2 Test Criteria

A material shall fail at the test conditions if it is ignited once in a maximum of 60 tests, or it shall pass at the test conditions if there is no ignition in 60 tests

*Typically, the test current is varied to determine the threshold for ignition of the material.*

#### A.11.3 Test Conditions

The following test conditions shall be determined by the OCA or by the test requester—test pressure, oxygen concentration, test specimen material/configuration, voltage, and current.

#### A.11.4 Specimen Preparation

The test specimen configuration shall be specified in the OCA or by the test requester.

*This preparation may include fraying the test materials with a wire brush.*

#### A.11.5 Test System

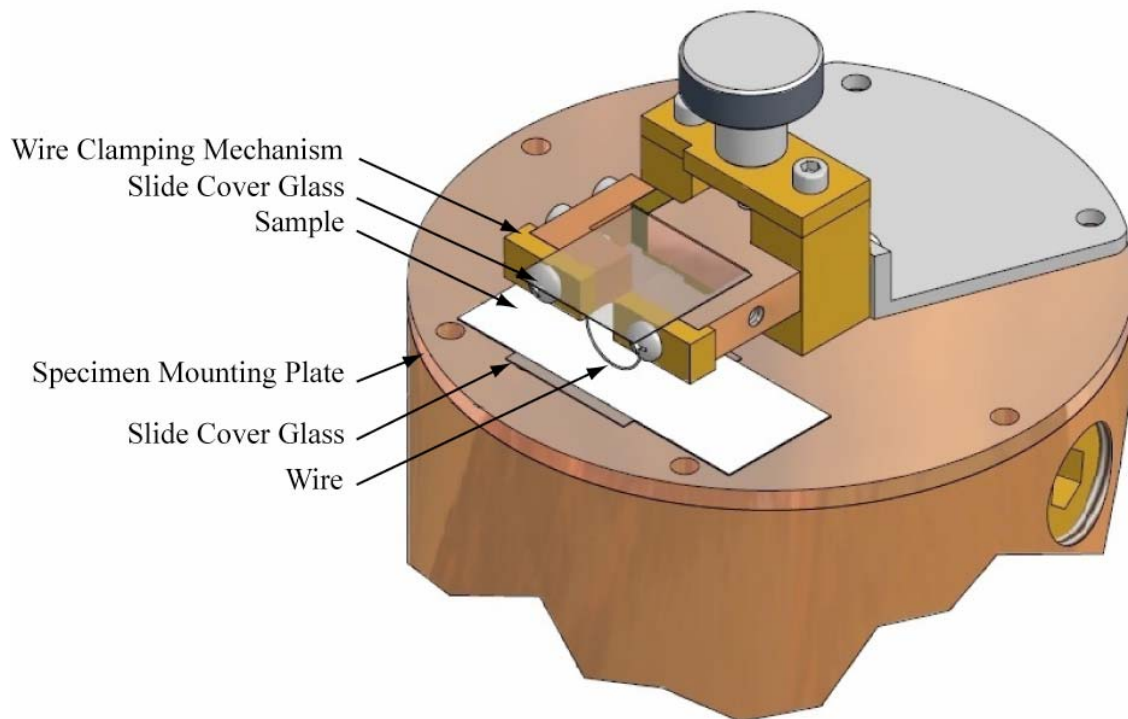
*Electrical arc tests are performed in a chamber pressurized as desired with oxygen or a specified gas mixture. The apparatus includes a single strand of wire in contact with the test material (figure 5). The test chamber is a stainless-steel cross with four 10.2-cm (4-in) ports. The test chamber accommodates a gas inlet and outlet, a view window for normal and high-speed video recording, a test specimen mounting block (with built-in heat exchanger for temperature control), a TCe for temperature measurement, and power for the electrical arcing. The system is capable of a maximum test pressure of 689 kPa*

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(100 psia). The power supply is designed to emulate batteries, while allowing flexibility for different voltages and currents during testing.



**Figure 5—Electrical Arc Test Apparatus**

**A.11.6 Test Procedure**

- a. Before testing begins, the test voltage is set to correspond to the predetermined test conditions, and the current is set slightly lower than the desired test conditions.
- b. The appropriate wire size is determined, and the wire is clamped into place.
- c. The test chamber is sealed, purged, and pressurized with the correct pressure and oxygen concentration.
- d. Power is then applied to the wire, and the test conductor manually increases the current until the wire breaks, creating an arcing event.
- e. If an ignition occurs, testing is continued at a lower current level.

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*f. If no ignition occurs, high-speed video and visual inspection are used to verify that the wire broke in the desired location and was touching the test specimen. Each test consists of one wire-break event, which is observed for visual evidence of test material ignition.*

### A.11.7 Reporting

The test report shall include specimen material and configuration, test pressure, oxygen concentration, and current/voltage required for ignition.

## A.12 Frictional Heating

### A.12.1 Purpose

*The GOX and LOX frictional heating tests are designed to evaluate a material's susceptibility to ignition by frictional heating. These tests include rotational friction tests and reciprocal friction tests. Frictional heating tests can be used to accomplish the following objectives:*

- a. To assess the ability of a pair of materials to convert mechanical energy to thermal energy during rubbing.*
- b. To determine the coefficient of friction and wear.*
- c. For rotational friction tests, to determine the minimum contact pressure ( $P$ ) required to ignite a test material specimen at a given linear surface velocity ( $v$ ). This product ( $Pv_{\text{ign}}$ ) is used to rank the relative ignition resistance of materials.*
- d. For reciprocal friction tests, to determine whether the materials will ignite at the test frequency profile and displacement of movement.*

### A.12.2 Test Criteria

The test criteria shall be defined in the OCA.

*For both rotational and reciprocal friction tests, ignition is detected typically by a significant and rapid temperature increase, displacement, or a change in pressure (an initial pressure drop followed by a pressure increase). After termination of the test, the test specimens can be inspected visually for consumption of material.*

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### A.12.3 Definitions

*Definitions of relevant terms used in the description of this test method are:*

P: Minimum contact pressure.

v: Linear surface velocity.

### A.12.4 Test Conditions

The test parameter values shall be determined by the OCA or by the test requester.

*The test parameters for frictional heating tests are pressure, oxygen concentration (for GOX tests), rotational speed (for rotational friction tests), frequency profile and displacement of movement (for reciprocal friction tests), normal force, and test specimen materials.*

*Most of the existing friction data was generated using rotational friction at the following standard set of conditions, which may be useful for comparing data:*

- a. The oxygen pressure is kept constant at 6.9 MPa (1000 psig) for GOX tests and 2.1 MPa (300 psig) for LOX tests.*
- b. The rotational speed is kept constant at 17,000 revolutions per minute (rpm).*
- c. The normal load is increased steadily from 0 at a rate of 1.6-1.7 N/sec (7-7.5 lbf/sec) to the point of specimen failure or to the maximum load capacity of the test system.*

*Any of these test conditions may be changed to meet the recommendations in the OCA.*

### A.12.5 Specimen Preparation

- a. The test specimen configuration shall be specified in the OCA or by the test requester.
- b. Before testing, the specimens shall be prepared according to the end-use application or by washing with a warm liquid detergent solution, rinsing with deionized water, and drying with GN<sub>2</sub>.
- c. The specimens shall then be sealed in polyethylene bags until test.

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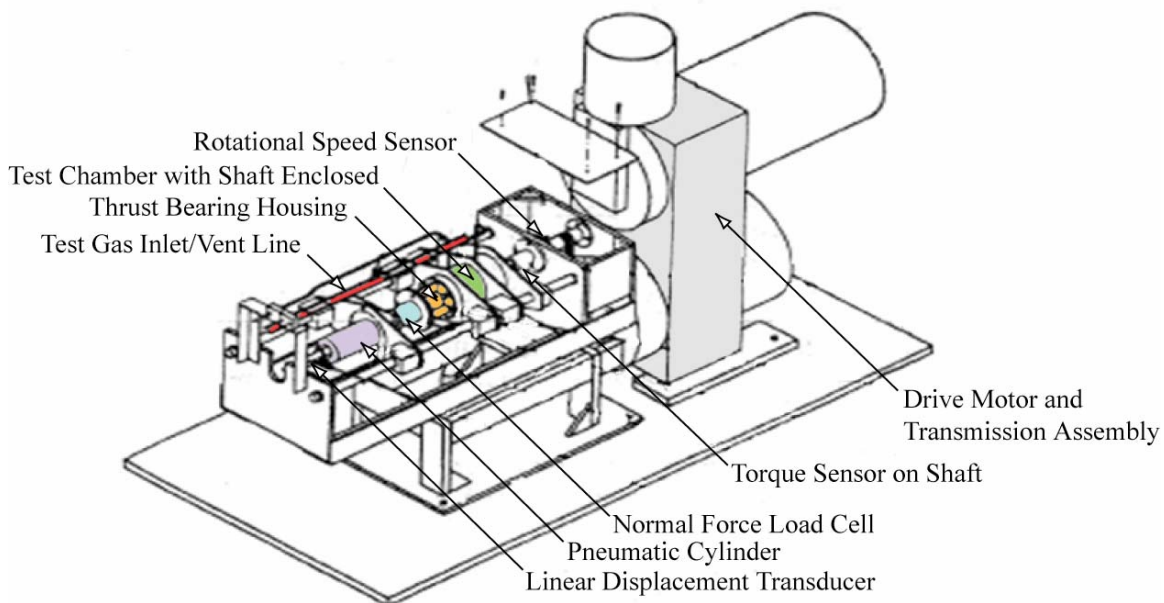
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d. From this point, the specimens shall be handled with clean, powder-free, lint-free gloves to maintain cleanliness.

*Most of the existing rotational friction data was generated with specimens configured as follows, which may be useful for comparing data:*

*For each rotational friction test, one test specimen remained stationary and one specimen rotated. The test apparatus was configured as shown in figure 6. Figure 7 shows test specimen configuration. The stationary test specimen had two small TC holes [0.1 cm (0.039 in) in diameter] drilled on its radial side. The rotational test specimens were fabricated similarly but without the 0.1-cm (0.039-in) diameter holes.*

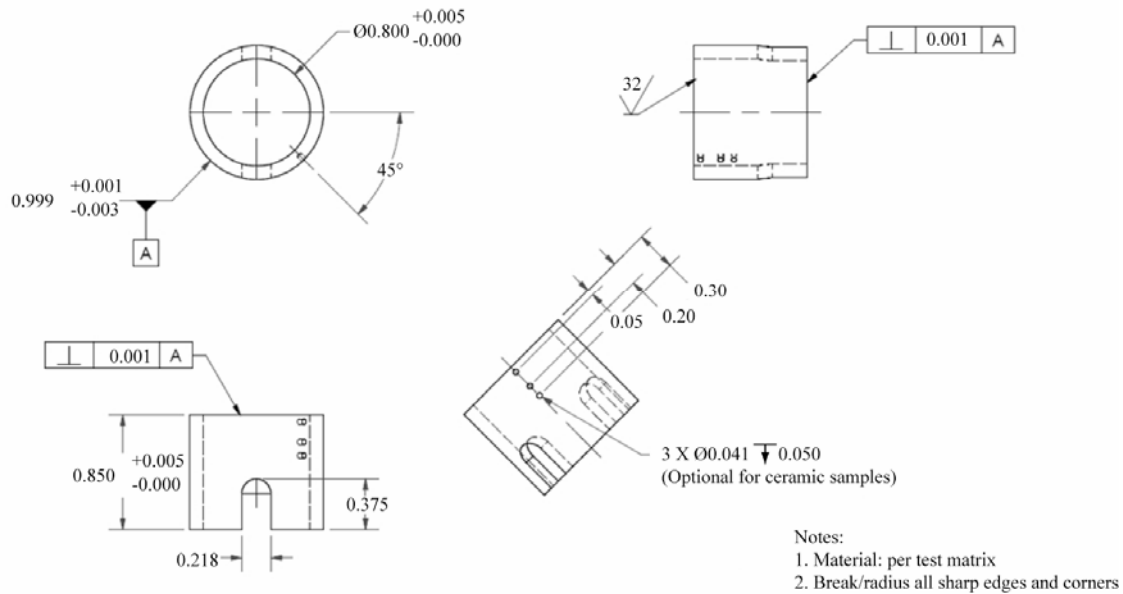


**Figure 6—Frictional Heating Test System**

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**Figure 7—Rotational Frictional Heating Stationary Test Specimen**

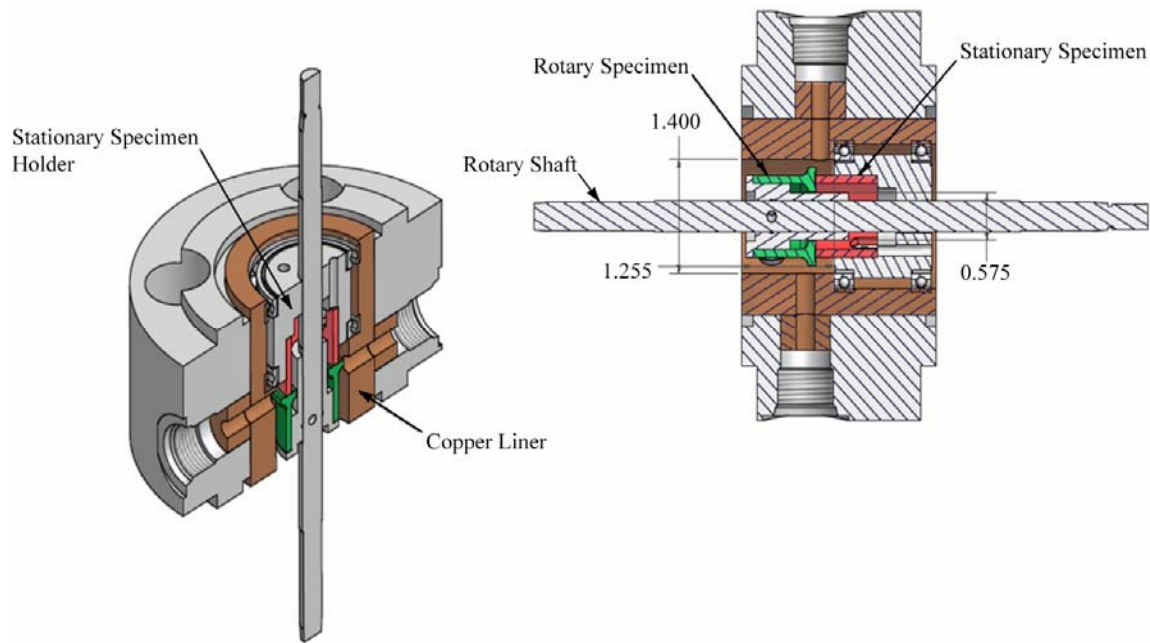
## A.12.6 Test System

*The test system varies, depending on which test is used and where the test is performed.*

*Most of the existing rotational friction data was generated using an apparatus similar to that shown in figures 6 and 8. This apparatus consists of a high-pressure test chamber, an electrical motor, a transmission assembly, and a pneumatic actuation cylinder. The chamber contains a rotating shaft that extends through the chamber by a series of bearings and seals. The shaft is connected at one end to a drive motor/transmission assembly that is capable of rotating the shaft at rotational speeds from 1000 to 27,000 rpm. The other end of the shaft is connected to a pneumatically actuated cylinder that allows axial movement of the shaft and provides the capability of applying a normal load of up to 4450 N (1000 lbf) to the test specimen. The rotating test specimen is mounted on the shaft, and the stationary test specimen is affixed to the test chamber.*

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**NASA-STD-(I)-6001A****Figure 8—High-Pressure Test Chamber**

*The rotating test specimen has an average linear surface velocity, relative to the stationary specimen, of approximately 20.5 m/sec (67.2 ft/sec) when the shaft rotates at 17,000 rpm.*

**A.12.7 Pre-Test Procedure**

*The pre-test procedure varies, depending on which test is used and where the test is performed.*

**A.12.8 Test Procedure**

*The test procedure varies, depending on which test is used and where the test is performed.*

**A.12.9 Reporting**

Results of frictional heating tests shall be summarized in a report that includes documentation of the specimen materials and configuration, the test conditions and apparatus, and test results. If the coefficient of friction is calculated from the data, it shall be included as well.

*Usually, pre- and post-test photographs of the test specimens are included in the report.*

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### A.13 Particle Impact Test

#### A.13.1 Purpose

*Particle impact tests are designed to evaluate the susceptibility of materials or components to ignition.*

*Particle impact tests can be used to accomplish the following objectives:*

*a. To determine the conditions at which ignition and consumption of a specimen material occurs when impacted by single or multiple particles entrained in a flow of GOX.*

*b. To determine if a specific material or component is subject to ignition and sustained combustion in a given flow environment when impacted by single or multiple particles entrained in a flow of GOX.*

#### A.13.2 Test Criteria

- a. The test criteria shall be defined in the OCA or by the test requester.

*The following criteria are typically applied:*

*For testing materials:*

*No ignition: Characterized by no evidence of combustion. A material that does not ignite may show one or more particle indentations on the surface of the material; these indentations may include localized erosion.*

*Ignition: A portion of or the entire specimen is consumed, and the target is not recoverable.*

*For testing components:*

*No ignition: Characterized by no evidence of combustion. A component that does not ignite may show one or more particle indentations on the inside surface of the component; these indentations may include localized erosion.*

*Ignition: Characterized by obvious consumption of the component, which may include burnout.*

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b. If a material is ignited once in a maximum of 60 tests, it shall fail the test at the test conditions; the material shall pass at the test conditions if there is no ignition in 60 tests.

*Typically for materials, the test conditions are varied to determine the threshold for ignition.*

c. For component tests, a minimum of 60 tests shall be performed at a single set of conditions on a single component. If there are no ignitions in 60 tests, the component shall pass testing. One ignition in 60 tests shall constitute failure of a component.

### A.13.3 Definitions

*Definitions of relevant terms used in the description of this test method are:*

High-velocity particle impact: Tests are performed using the supersonic particle impact test fixture. Gas stream velocities in this test system are supersonic ( $> \text{Mach } 1$ ). Gas velocities vary with the temperature and pressure of the oxygen system.

Low-velocity particle impact: Tests are performed with the subsonic particle impact test fixture. Gas stream velocities in this system are up to 600 ft/sec.

### A.13.4 Test Conditions

a. The following test conditions shall be determined by the OCA or by the test requester: gas/target temperature, target pressure, gas velocity, target material/configuration, and particle configuration (size, material, and quantity).

b. Components shall be tested at the worst-case conditions as determined by the OCA or by the test requester.

*Typically, material tests are performed with 2000- $\mu\text{m}$  (0.08-in) diameter aluminum 2017 particles at supersonic velocity and an upstream test pressure of 27.6 ( $\pm 0.7$ ) MPa [4000 ( $\pm 100$ ) psig]. These conditions may be considered the standard test conditions with which to rank materials against each other for resistance to ignition by particle impact. The majority of the supersonic data generated was generated at this standard set of conditions.*

### A.13.5 Specimen Preparation

a. The test specimen configuration shall be specified in the OCA or by the test requester.

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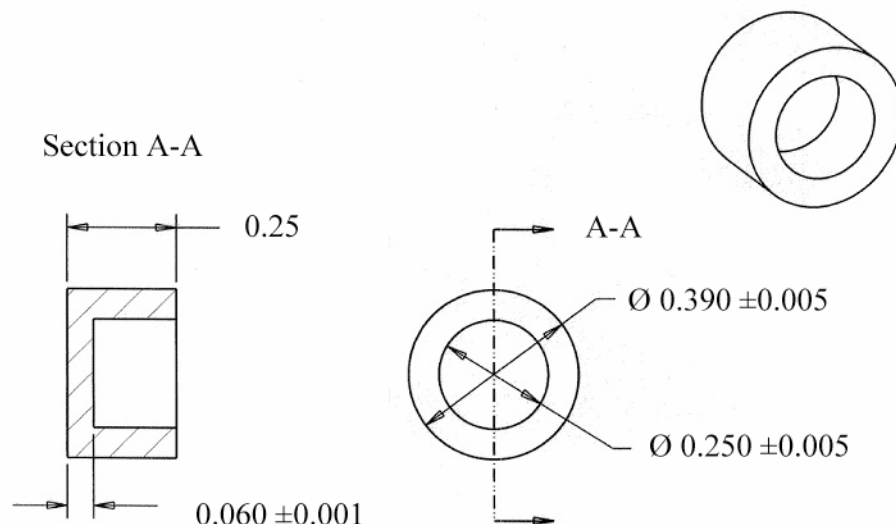
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- b. Before testing, material specimens shall be prepared according to the end-use conditions or by washing with a liquid detergent solution, rinsing with deionized water, and drying with GN<sub>2</sub>.
- c. The specimens shall then be sealed in clean polyethylene bags until testing.
- d. From this point on, the targets shall be handled with powder-free, lint-free gloves to maintain cleanliness.
- e. The configurations of test targets for the low- and high-velocity testing shall be as follows:

### (1) Material Specimens.

*High-Velocity Particle Impact Material Specimen Preparation (figure 9): These specimens are cup-shaped with an outside diameter of 0.99 cm (0.390 in) and a target surface thickness of 1.5 cm (0.060 in). Each specimen is press fit onto a copper specimen holder for testing.*



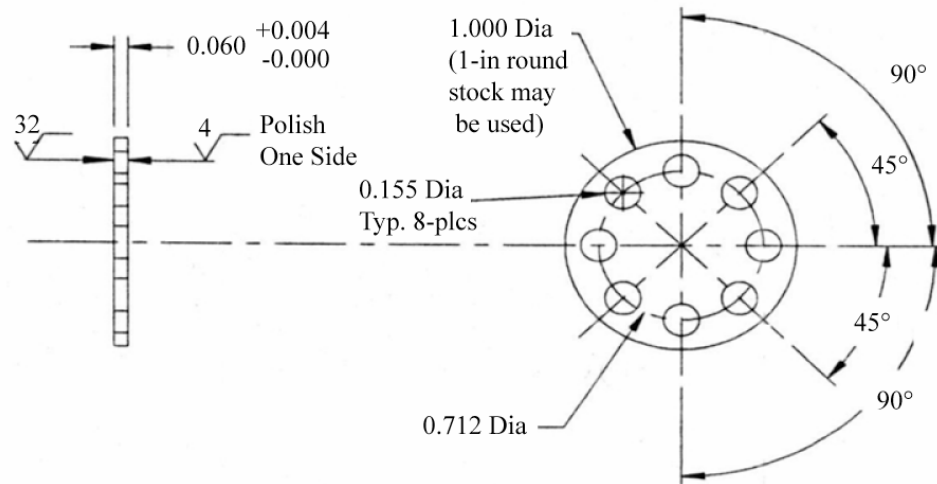
**Figure 9—High-Velocity Particle Impact Target Specimen Configuration**

*Low-Velocity Particle Impact Material Specimen Preparation (figure 10): These specimens are configured as flat discs, 1.5 cm (0.060 in) thick, with holes drilled radially to allow flow through the outer edge of the target.*

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**Figure 10—Low-Velocity Particle Impact Target Specimen Configuration**

- (2) Component Testing: Components shall be configured in their end-use configuration.

*Components can be adapted to either the high- or low- speed test systems.*

## A.13.6 Test System

- a. Particle impact tests shall be conducted in a facility capable of supplying heated GOX at the desired test pressure.
- b. High-velocity particle impact test system: The test specimen shall be placed on a mounting post directly in line with the gas flow stream.

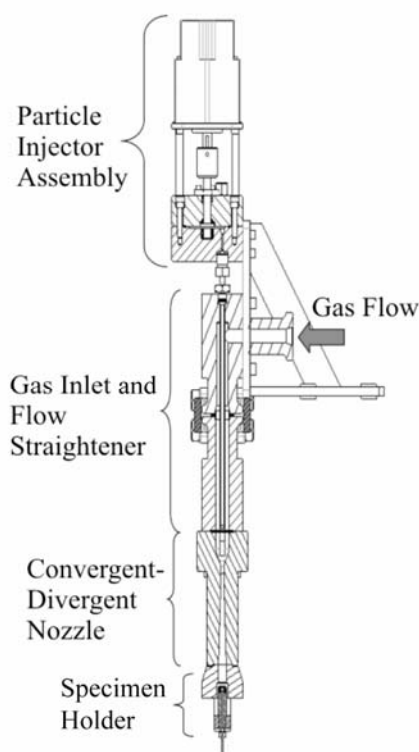
*The high-velocity particle impact test system (figure 11) consists of four major sections: the particle injector assembly, gas inlet and flow straightener, converging-diverging nozzle, and specimen holder. GOX enters the system at subsonic velocities. As the gas enters the converging portion of the nozzle and continues into the throat, it accelerates to a velocity of ~Mach 1. The gas expands as it enters the diverging portion of the nozzle and accelerates to supersonic velocities. The gas stream impinges on the specimen face,*

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*creating a stagnation pressure, and flows around the specimen. (This stagnation pressure is lower than the upstream pressure.)*



**Figure 11—High-Velocity Particle Impact Test System**

*The following describes testing steps for one test facility's configuration; other facility configurations may lend themselves to variations of this description:*

- (1) A bare wire TC is sandwiched between the back face of the test specimen and the specimen post.*
- (2) The post is placed in a quick-change holder, which mounts on the outlet of the convergent-divergent nozzle.*
- (3) The upstream oxygen pressure is measured by two bonded strain-gauge pressure transducers located upstream of the inlet.*
- (4) The flow stream (oxygen) temperature is measured by a Type-T TC located in approximately the same location.*

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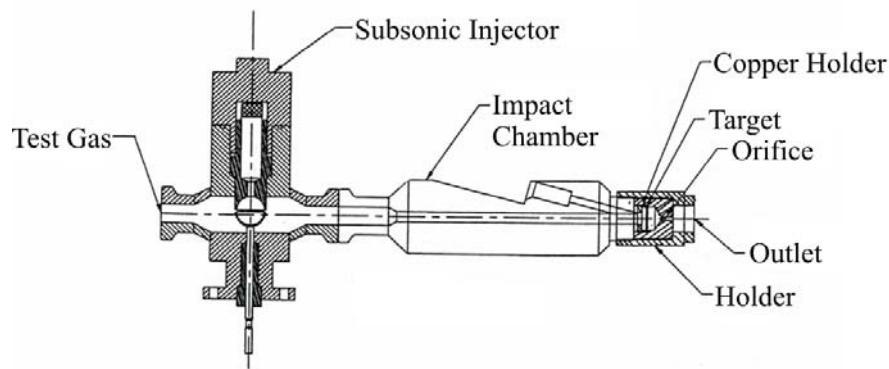
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- (5) *The bare wire TC, mounted behind the specimen, measures the test specimen temperature. This temperature is reported as the test temperature.*

c. Low-velocity particle impact test system:

*The low velocity test system delivers oxygen gas at velocities up to 183 m/sec (600 ft/sec), and it consists of the particle injector, the flow straightener, and the impact chamber (figure 12).*



**Figure 12—Low-Velocity Particle Impact Test System**

- (1) A flow orifice, sized to produce the desired gas velocity, shall be placed immediately downstream of either the material specimen or component.
- (2) GOX shall enter the particulate injector at subsonic velocities and shall flow through the flow straightener section and around the target specimen in the impact chamber.

*The following describes testing steps for one test facility's configuration; other facility configurations may lend themselves to variations of this description.*

*The upstream oxygen pressure is measured by a bonded strain-gauge pressure transducer mounted in the flow straightener of the test fixture, located upstream of the inlet.*

*The flow stream (oxygen) temperature is measured by a Type-T TC located in approximately the same location. This temperature is reported as the test temperature.*

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### A.13.7 Test Procedure

*The following steps describe the testing procedure for one test facility's configuration; other facility configurations may lend themselves to variations of this description:*

- a. Particles are loaded into the particle injector, and the test material or component is configured for testing.*
- b. A video camera is used to record the test.*
- c. GOX at the desired test pressure and temperature is allowed to flow until the temperature of the target specimen or component is achieved and the gas flow stabilizes.*
- d. The particle(s) are injected into the flow stream.*
- e. After impact, the oxygen flow is terminated, and the test system is allowed to vent to ambient pressure.*
- f. To verify that particle impacts have occurred, the presence of a flash is noted, and the target specimen or component is inspected visually.*
- g. At the completion of test data storage and specimen inspection, the procedure is repeated until the specimen has either passed or failed testing.*

### A.13.8 Reporting

Results of particle impact tests shall be summarized in a report that includes documentation of the specimen target material or component, the particle material and size, the test conditions, and the response of each target to impact.

*Typically, pre- and post-test photographs of the test specimens are included in the report.*

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### APPENDIX B

#### CERTIFICATION OF FACILITIES

**B.1** Certification of test facilities shall be obtained for the performance of any of the required tests included in this document.

*Certification is necessary because data from these tests will be presented for materials selection approval.*

**B.2** Certification shall be the responsibility of a panel appointed by the NASA Headquarters Office of the Chief Engineer.

**B.3** The panel shall consist of M&P representatives from NASA-certified facilities and shall be supported by specialists in appropriate disciplines to evaluate specific test methods.

**B.4** An application for certification shall be submitted according to requirements listed below:

a. The test facility applying for certification shall prepare and submit detailed written procedures to perform all aspects of the subject test methods to the certification panel for review.

b. The procedures shall include provisions for instrument calibration, specimen preparation, test chamber certification, test atmosphere analysis or verification, data analysis, report preparation, quality control provisions, recording and archiving of test data, materials control, and control of flight articles.

c. The test facility shall also include in this procedure the definition of the minimum acceptable personnel qualifications, training requirements, and personnel certification procedures.

d. Changes to these procedures shall be maintained and made available at the request of the certification panel.

e. The test facility also shall supply documentation demonstrating that operations performed in the subject test methods present no hazards to personnel or flight hardware.

*Facilities certified to ISO/IEC 17025, General requirements for competence of testing and calibration laboratories, are considered to have met the requirements of paragraph B.3.*

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**B.5** The certification panel shall perform an on-site inspection of the test facility to ensure that the test facility can perform the methods from receipt of a material to issuance of a final report.

**B.6** The certification panel shall recommend to the NASA Office of the Chief Engineer certification of the test facility on the basis of compliance with this document.

*The NASA Chief Engineer has the authority to certify the facility.*

**B.7** The certification panel shall maintain certification records.

**B.8** NASA certification of a test facility shall be maintained by meeting the following requirements:

- a. The test facility shall perform the required test method(s) for which it is certified and shall have reported the data to MAPTIS at least once within the last 18 months.
- b. The test facility shall have participated with other NASA-certified test facilities in the most recent round-robin testing for the test method.
- c. Round-robin tests for Test 1, Test 4, and Test 7 shall be conducted at least every 2 years.
- d. The test data shall have been reviewed and approved by the certification panel or the panel's designees.
- e. Facility test procedures shall be available for audit by the certification panel.

**B.9** All instrumentation used in the test shall be in current calibration and, where available, shall bear the appropriate documentation to validate traceability to the appropriate national, international, or intrinsic measurement standards.

**B.10** The test facility shall ensure and certify that all testing is accomplished in accordance with approved test plans and procedures and that the data records and test results are complete and accurate.

**B.11** Complete test records shall be prepared by the test facility for each material or system tested.

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**B.12** The test facility shall maintain a permanent record of test data for a minimum of 15 years for historical purposes.

**B.13** Records and data shall be submitted to MAPTIS in the acceptable format.

*NASA reserves the right to conduct an on-site audit of any certified test facility at any time.*

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### APPENDIX C

#### REFERENCE DOCUMENTS

*This publication references the following documents (latest revisions available at the time of publication):*

##### NASA

JSC 29353A (2007)	Flammability Configuration Analysis for Spacecraft Applications
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##### ISO

ISO 14624-4:2003	Space systems — Safety and compatibility of materials — Part 4: Determination of upward flammability of materials in pressurized gaseous oxygen or oxygen-enriched environments
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ISO/IEC 17025:2005	General requirements for competence of testing and calibration laboratories
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**C.1.** Any use of a different version shall be specified or approved by the responsible NASA Center's M&P organization.

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### APPENDIX D

#### SUBMITTING MATERIAL FOR TESTING

*The quality of the data obtained from the test material or assembled article is dependent on the proper identification and packaging of the material/assembled article for submission for test.*

*Failure to follow good practice may result in unnecessary delays or a loss in confidence in the data obtained.*

##### **D.1 Submitting Material**

**D.1.1** The test material shall be free of flaws and visual contamination.

**D.1.2** *The minimum quantity of material to be submitted for each test is shown in table 3.*

**D.1.3** *Solid material should be packaged in a visibly clean, sealed bag, e.g., zip-locked, heat-sealed, taped, that is compatible with the specimen material. The test material name, as specified by the manufacturer, should appear on the exterior of the bag; the material itself should not be marked. Non-solid materials may be packaged in the original manufacturing container.*

**D.1.4** *Electrostatic-discharge-sensitive items and hardware should be packaged in accordance with their end-use specification.*

##### **D.1.5 Documentation**

- a. The MSDS shall be provided.
- b. If the test facility is to prepare material specimens, the manufacturer's literature or preparation instructions, at a minimum, shall be provided.
- c. A completed test request form (section D.2) shall be submitted.

*Table 6 provides a key for completing the Test Information section of the test request form.*

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**Table 6—Key for Completing “Check Test(s) to be Performed” Section**

Test Number	Test Title
1	Upward Flammability
2	Heat and Visible Smoke Release Rate
3	Flash Point of Liquids
4	Electrical Wire Insulation Flammability
6	Odor Assessment
7	Determination of Offgassed Products
10	Configurational Flammability
13a	Mechanical Impact for Materials in Ambient Pressure LOX
13b	Mechanical Impact for Materials in Variable Pressure GOX and LOX
15	Reactivity of Materials in Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia
17	Upward Flammability of Materials in GOX
18	Arc Tracking
AIT	Autogenous Ignition Temperature
EA	Electrical Arc
FH	Frictional Heating
GFI	Gaseous Fluid Impact for Components
HC	Heat of Combustion
IE	Reactivity and Penetration of Materials due to Incidental Exposure to Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia
OCA	Oxygen Compatibility Assessment
OI	Oxygen Index
PI	Particle Impact
Special	Other tests (not governed by NASA-STD-6001A), e.g., Volatile Condensable Material

### D.2 Test Request Form

*Figure 13 is an example test form. The exact format may vary, depending on the test facility.*

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Requester Information		Facility to Complete										
*Name:	Name:	Facility I.D. No.										
*Organization:	Organization:											
*Address:	Address:	Requester Tracking No.										
E-Mail:	E-Mail:	Request Date										
*Phone:	Phone:	Material Code:										
Material/Assembly Information												
*MSDS Attached? Yes <input type="checkbox"/> No <input type="checkbox"/>		*Manufacturing Literature Attached? Yes <input type="checkbox"/> No <input type="checkbox"/>										
*Material/Assembly Name/Designation:		Part Number:	Serial Number:									
Batch/Lot #:		Chemical Class:										
Specification:		*Program:	Flight Hardware									
Cleaning Specification/Method:		*Project:	Yes <input type="checkbox"/> No <input type="checkbox"/>									
Other (date of manufacture, composition, color, acronyms, etc.)												
Manufacturer Information		Supplier Information										
*Name:		Name:										
*Address:		Address:										
*Phone:	Web Address:	Phone:	Web Address:									
*Test Information												
Check test(s) to be performed:												
1	2	3	4	6	7	10	13a	13b	15	17	18	AIT
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EA	FH	GFI	HC	IE	OCA	OI	PI	Special:				
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				
*Number of Specimens Provided:		*Use Atmosphere/Fluid:		*Use Thickness:		Intended Application:						
*Test Atmosphere		*Test Pressure		*Test Temperature								
Mass:		Dimensions:		*Photographic Coverage: Video <input type="checkbox"/> Stills <input type="checkbox"/> None <input type="checkbox"/>								
*Is test data/information restricted? Yes <input type="checkbox"/> No <input type="checkbox"/>						Restriction:						
Cure Information												
*Is cure required? Yes <input type="checkbox"/> No <input type="checkbox"/>						*Has requester performed cure? Yes <input type="checkbox"/> No <input type="checkbox"/>						
*Provide cure method, whether performed by requester or to be performed by test facility, in the following table:												
Step	Time (hr)	Mix Ratio (if applicable)					Temperature (°F)			Pressure (psia)		
1.		Weight <input type="checkbox"/> Volume <input type="checkbox"/>										
2.		Weight <input type="checkbox"/> Volume <input type="checkbox"/>										
3.		Weight <input type="checkbox"/> Volume <input type="checkbox"/>										
Notes/Remarks/Special Instructions												

\* Required information

## Figure 13—Representative Test Request Form

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