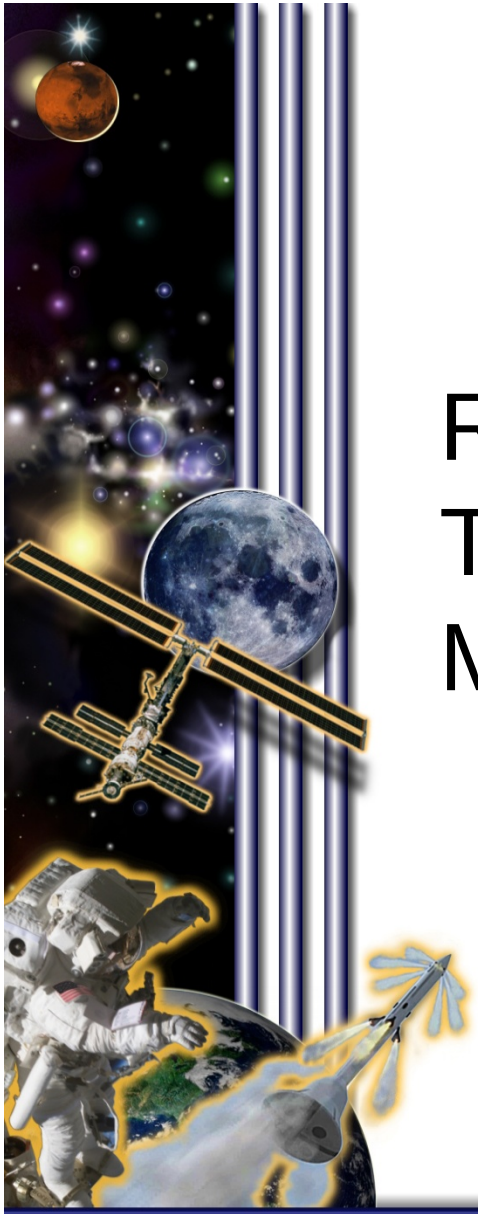

Remarks on Flammability Testing of Aerospace Materials

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Agenda

- Brief background of ISO 16697
  - Reasons for the approach
  - Stated intent for this International Technical Specification
- Evolution of initial considerations for the ISO approach
- Discussion and recommendations

Brief Background of ISO 16697

- NASA STD 6001 Tests 1 and 4 data correlation issues.
- Flammability threshold approach – implemented in 2011 as ISO Technical Specification 16697.
- The method allows to determine the self-extinguishment limits of one parameter (oxygen concentration, or total pressure, or microgravity level, etc.) while keeping other parameters constant.
- It is important to note that with the exception of the pass/fail test logic, ISO 16697 follows NASA STD 6001 Test 1 (or Test 4).

Why the ISO 16697 Approach (besides the data correlation issues)

- Large NASA STD 6001 flammability database with live actual aerospace applications (Space Shuttle at the time, in 2002; ISS).
- Very little (if any) existing micro- or reduced-gravity flammability threshold data at the time.
- Perceived need for enhanced precision and accuracy mostly for immediate research applications related to data correlation.

Stated Intent of ISO 16697

- The intent is being called out in the Introduction Section
- “To bring to the attention of International Aerospace Community the importance of correlating laboratory test data with real-life space systems applications.”
- It is emphasized that “The method presented is just one of possibilities that are believed will lead to better understanding the applicability of laboratory aerospace materials flammability test data”.
- “International feedback on improving the proposed method, as well as suggestions for correlating other laboratory aerospace test data with real-life applications relevant to space systems are being sought.”

Evolution of Initial Considerations for the ISO 16697 Approach

- On-going work on correlating ground flammability test data and data in micro- and reduced-gravity based on flammability threshold.
- There are experimental constrains in spacecraft and ground microgravity flammability testing. By necessity, this work has to be conducted with samples of different configurations, ignition mode, perhaps pass/fail criteria than the ones used by NASA STD 6001.
- Current correlations (A to B to C) are more complex (i.e. correlate NASA STD 6001 configuration to spacecraft test configuration to spacecraft microgravity environment) Increased uncertainty associates this complexity.

Evolution of Initial Considerations: Phenomenology Related to Precision and Accuracy

- Statistical uncertainty and phenomenological uncertainty analyzed statistically.
- Ex. Uncertainties associated with attribute (pass/fail) data: Binomial cumulative probability P of k samples failing in n tests for a material with a p failure probability.

Probability of at least one sample failing under a set of conditions (%)	Probability of no failures observed in n tests under the same conditions (%)			
	n = 3	5	10	20
10	73	59	35	12
5	86	77	60	36
1	97	95	90	82

Evolution of Initial Considerations: Observations on Phenomenological Uncertainty

- ISO 16697 appears to provide high precision data (i.e considering data linearity related to pressure effects on the oxygen concentration threshold [1]).
- The range between the highest oxygen concentration at which all samples tested (5) pass and the oxygen concentration at which 50% of samples pass is relatively small (mostly 1 to 3% for materials with MOC's up to 30%); This range appears to increase with increasing MOC's;
- It appears that the curve describing the dependence of probability of failure with oxygen concentration is abrupt (close to verticality); i.e the probability of a sixth sample failing upon a series of five samples passing is relatively low. Consequently, it is possible that an acceptable accuracy may be achievable with a less rigorous statistical approach.

Other Observations

- An earlier study [2] compared the oxygen concentrations at which 50% of samples passed (the oxygen limiting index as accepted by the combustion community) for two methods.
- One method consisted of an upward flammability test conducted in a LOI apparatus in flowing environments (4 cm/s surface velocity); the second method consisted of a modified NASA STD 6001 test conducted in a quiescent environment in a 1400-L chamber. The test logic of NASA STD 6001 has been modified to allow evaluation of the 50% passing point.
- The data indicates that for most materials tested (PMMA, HDPE, POM, PA, PU) the 50% passing points were nearly identical.

Discussion and Recommendations

- The flammability threshold testing approach can provide data which allows comparing ground test data with data in spacecraft environments; additionally, the data obtained is applicable for various spacecraft environments and will not require extensive re-testing if the design parameters of new spacecraft are changed.
- The specific version for a ground standard test method should be further investigated considering the micro and reduced-gravity combustion research needs and approaches, an acceptable compromise on testing cost vs data accuracy, etc.