Remarks on Flammability Testing of Aerospace Materials

David B. Hirsch
Harold D. Beeson

NASA/JAXA Technical Interchange Meeting
NASA WSTF
Las Cruces, NM USA
March 8, 2013
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.
• 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.
• 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.”
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 |
• 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.
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.
• 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.