National Aeronautics and Space Administration

NASA Engineering and Safety Center Technical Bulletin No. 26-03

Flammability Testing Configuration and Approach of Barrier Material Assemblies Designed for Space Flight Applications

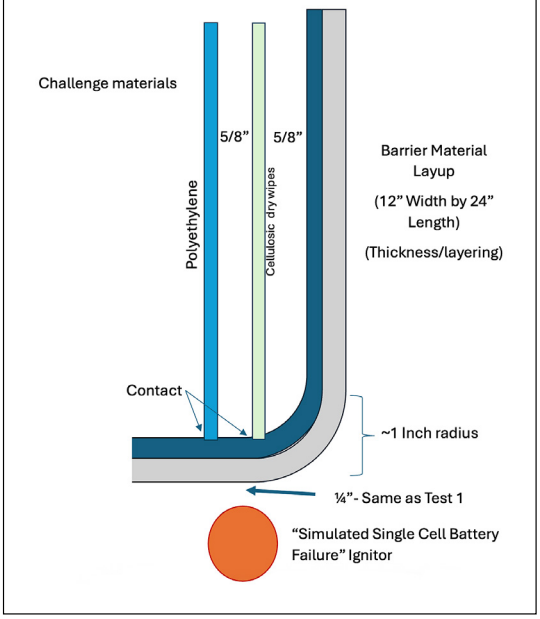
The NASA Engineering and Safety Center (NESC) partnered with Materials and Processes and Flammability subject matter experts from the Johnson Space Center, White Sands Test Facility, and the Marshall Space Flight Center to design and develop a test for evaluating the effectiveness of material assemblies to serve as a barrier between a potential cabin ignition source based on typical flammable materials in the habitable volume of spacecraft.

Background on Barrier Material Flammability Testing

The standard "three-legged" approach to material flammability mitigation, including material controls, ignition source controls, and robust fire response, outlines a fire safety management plan in which misses or weaknesses in one leg are compensated for by others. The material control leg is based on selecting non-propagating materials for use in spacecraft. Verification of non-propagating materials is based on NASA-STD-6001B, Flammability, Offgassing, and Compatibility Requirements and Test Procedures (in this case, Test 1 for upward flammability). However, when not all materials pass the upward flammability test, additional mitigation strategies are required. Some of these include designing layups to serve as heat sinks, inhibiting propagation paths through controlled spacing and surface area, and shielding or enclosing flammable materials using barrier layups. Barrier materials are those designed to provide shielding between ignition sources and flammable materials. Their use for storage and broad acreage cabin surfaces has historically provided a hazard control justification for the use of highly flammable items such as crew clothing, hygiene items, etc. Accordingly, they must be "non-breaching" in addition to "non-propagating." The standard "Test 1" materials test for flammability does not evaluate breaching, resulting in a gap in test capability to assess these flammability mitigation designs.

In 2023, testing of fully assembled barrier hardware and material lay-ups was performed at White Sands Test Facility to evaluate their effectiveness in providing flammability protection. The testing identified gaps with the current test approach outlined in the NASA standard, particularly for combinatorial configurations (e.g., seams, zippers, etc.). In 2024, NASA Johnson Space Center materials and processes engineering community released a memo (JSC-ES4-24-030) explaining that the NASA-STD-6001 Test 1 upward flammability test is not sufficient to evaluate the materials and layups used in barrier hardware. In response, the NESC undertook development of a test to evaluate barrier materials and layups. Subject matter experts from multiple centers collaborated with the NESC in designing, developing, testing, and evaluating the new methodology.

Graphic Representation of Barrier Testing Configuration



Barrier Flammability Testing Development

Development of the barrier test methodology involved determining the parameters associated with barrier hardware testing. Assessed parameters were ignition energy including determining temperature and burn duration encompassing possible ignition sources, barrier material test configuration ("L" shape of pliable materials with challenge material "inside"), challenge material makeup, number of replicates, and pass/fail criteria. The team tested barrier assemblies and challenge material configurations to envelope the maximum burn time and temperature of flight-like potential ignition sources and materials. The team tested multiple ignitor configurations, different chemical types, and a range of ignitor quantities to envelope the potential burn durations and peak temperatures of common cabin materials including batteries. Ignitor configurations were tested with control materials to ensure the ignitor was not overly conservative but informing margin and that the test encompassed the range of currently proposed barrier material configurations. A statistical analysis of the Materials and Processes Technical Information System (MAPTIS) database for Test 1 data helped determine the appropriate number of replicates needed to provide further confidence and reliability in the test process and results. The new barrier test calls for 5 replicates as a baseline. However, if charring is observed on the interior of the barrier greater than 3" away from the ignitor impingement point material or if challenge material heat affected lengths are observed to be greater than 3", then the number of replicates is increased from 5 to 10 to reduce uncertainty. Pass/fail criteria was determined with the goals of ensuring that a cabin fire of known cabin flammables could not lead to a larger fire due to ignition and propagation of the barrier assembly itself or of shielded flammable materials due to a barrier breach. Details of the test protocol and assessment criteria will be presented at the International Conference on Environmental Systems.

Barrier Flammability Testing Configuration/Parameters

Test Fixture:
- Large fixture to eliminate edge effects (12" width x 24" length, 1" bend radius).
- "L" shaped fixture eliminates concerns for oxygen depletion and tests potential upward propagation component in the event of barrier breach/ flame propagation.

Challenge Materials:
- Based on worst case autoignition temperature (AIT) materials that may be present in the cabin.
- Materials: Polyethylene (AIT 306°C), Cellulosic dry wipes (AIT 386°C), (AITs at 100% oxygen, 1500 PSI).
- Suspended vertically above ignitor fire impingement point as in Test 1. Lower edge of challenge materials configured with ½" wide, 1.5" long slits with lower edges in contact with inner layer of barrier material under test.

Ignition Source (Size/ Energy):
- "Simulated Single Cell Battery Failure" Ignitor: Standardized ignitor bounds worst case realistic temps/ durations by simulating a single cell battery failure.

Pass/ Fail Criteria:
- Full upward propagation of assembly materials - **FAIL**
- Sustained combustion of challenge material - **FAIL**
- Burn through hole observable with the naked eye post-test - **FAIL**
- If charring observed on the interior of the barrier greater than 3 inches away from ignitor impingement point material OR if challenge material heat affected lengths are observed to be greater than 3", then the number of replicates is increased from 5 to 10 to reduce uncertainty (samples in the 5 additional replicates demonstrating heat affected zones greater than 3 inches away from intimate contact area will not constitute failure but reduce uncertainty that ignition of the challenge material is unlikely).

References

1. NASA-STD-6001B, Flammability, Offgassing, and Compatibility Requirements and Test Procedures, June 9, 2025
2. ES4-24-030 NASA STD-6001 Clarification, 2024



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11/04/26 DOC ID: 20260001542