Pressure Flammability Thresholds of Selected Aerospace Materials

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I. Abstract
A test program was performed to determine the highest pressure in oxygen where materials used in the planned NASA Constellation Program Orion Crew Exploration Vehicle (CEV) Crew Module (CM) would not propagate a flame if an ignition source was present. The test methodology used was similar to that previously used to determine the maximum oxygen concentration (MOC) at which self-extinguishment occurs under constant total pressure conditions. An upward limiting pressure index (ULPI) was determined, where approximately 50 percent of the materials self-extinguish in a given environment. Following this, the maximum total pressure (MTP) was identified, where all samples tested (at least five) self-extinguished following the NASA-STD-6001.A Test 1 burn length criteria. The results obtained on seven materials indicate that the non-metallic materials become flammable in oxygen between 0.4 and 0.9 psia.

II. Introduction
The Environmental Control and Life Support Systems (ECLSS) of the Crew Exploration Vehicle (CEV) Crew Module (CM) is designed for a leak rate equivalent to a 1/4-in. hole to maintain a cabin pressure of 8 psia for one hour, during which the astronauts would don their space suits. The crew would then breathe 100 percent oxygen from the space suit oxygen supply while the cabin is allowed to depressurize towards vacuum. Ultimately, the only gas in the CM cabin would be oxygen at near vacuum pressures from suit leakage. The concern is that cabin materials might be more flammable in oxygen at near vacuum pressures than in the CEV cabin materials certification environment of 30 percent oxygen at 10.2 psia. Therefore, this program was conducted to determine the highest pressure in nearly 100 percent oxygen at which typical spacecraft materials are still self-extinguishing.

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III. Experimental Apparatus

The materials evaluated included plastics (polysulfone and a polyvinylchloride/polyvinylchloride alloy), an epoxy/fiberglass laminate, an aramid fabric, films (polyetherimide and polyethylene terephthalate), and a polyimide foam. These are summarized in Table 1. All samples were 2.5-in. wide and 6-in. long. The Nomex® samples were tested as a single layer with a double-rolled hem on the bottom and side edges. The equipment used and the experimental approach were similar to previous experiments.

Pressure flammability threshold tests were conducted in a quiescent environment in a closed 1400-L flammability chamber connected to vacuum, oxygen, and nitrogen supplies. The testing was conducted in 99.8 percent oxygen, sequentially following the “up-and-down method for small samples” and using a step size of 0.1 psi. The NASA-STD-6001 Test 1 burn length criterion was used; a sample was considered self-extinguishing if its burn length was less than 6 in. The upward flammability limiting pressure indices (ULPIs) were evaluated statistically; the ULPI represents the total pressure at which a material passes the NASA-STD-6001 Test 1 burn length criteria approximately half the time. The maximum total pressures (MTPs) that consistently resulted in self-extinguishment, i.e., where all samples (at least five) pass the Test 1 burn length criterion, were also determined.

V. CONCLUSIONS AND RECOMMENDATIONS

Parametric flammability thresholds other than oxygen concentration can be determined with the methodology proposed for evaluating the maximum oxygen concentration (MOC) when extinguishment occurs under given conditions. In this case, a pressure threshold in 99.8 percent oxygen was determined by the methodology and found to be 0.4 to 0.9 psia for typical spacecraft materials. Correlation of flammability thresholds obtained with chemical, hot wire, and other ignition sources will be conducted to provide recommendations for using alternate ignition sources to evaluate flammability of aerospace materials.

VI. Acknowledgments

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* NASA-STD-6001. A Test 1 uses a 12-in. long sample. Since insufficient material was available for all samples to be 12-in. long, 6-in. samples were used, which won’t impact the value of MTP. At the MTP, none of the samples burned more than 1-in.

† Nomex® is a registered trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

‡ Melinex® is a registered trademark of Imperial Chemical Industries Limited Corporation, Great Britain Imperial Chemical House, London, England.
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VIII. Notes

*Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.
References


Table 1. Selected polymeric materials evaluated in this study.

<table>
<thead>
<tr>
<th>Material</th>
<th>ULPIa</th>
<th>MTPb</th>
<th>ULOIb</th>
<th>MOCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy/glass</td>
<td>0.9</td>
<td>0.8</td>
<td>28.6</td>
<td>24</td>
</tr>
<tr>
<td>Udel P1700</td>
<td>1.0</td>
<td>0.9</td>
<td>31.7</td>
<td>29</td>
</tr>
<tr>
<td>Kydex 100</td>
<td>1.8</td>
<td>0.6</td>
<td>33.5</td>
<td>32</td>
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<tr>
<td>Solimide TA-301</td>
<td>0.7</td>
<td>0.5</td>
<td>29.3</td>
<td>28</td>
</tr>
<tr>
<td>Melinex 515</td>
<td>0.9</td>
<td>0.4</td>
<td>21.2</td>
<td>20</td>
</tr>
<tr>
<td>Nomex HT90-40</td>
<td>0.6</td>
<td>0.5</td>
<td>28.5</td>
<td>25</td>
</tr>
<tr>
<td>Ultem 1000</td>
<td>1.5</td>
<td>0.9</td>
<td>26.5</td>
<td>24</td>
</tr>
</tbody>
</table>

a ULPIs and MTPs have units of psia and were determined in 99.8% oxygen.
b ULOIs and MOCs have units of % oxygen by volume and were determined at 10.2 psia.

Table 2. Pressure and oxygen concentration flammability limits for selected materials.