Pressure and Quantity Thresholds for Ignition of Oil Contamination by Rapid Pressurization in Oxygen Systems

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Problem Statement

• Problem:
  – Oil contamination produces an increased ignition hazard in oxygen systems

• Solution:
  – Determine oil quantity and oxygen pressure thresholds
Experimental

• Perform rapid pressurization tests
  – Common ignition mechanism in oxygen systems

• Contamination level threshold
  – Determine quantity of oil (sebum) deposited by handling hardware with bare hands
  – Determine quantity of oil (sebum) required to obtain a burning reaction during rapid pressurization to 4000 psi

• Oxygen pressure ignition threshold
  – Use highly volatile hydrocarbon oil (WD-40) on open-cell polyethylene foam
  – Determine minimum ignition threshold as a function of pressure
Contamination Level Threshold

- The oil on the surface of the skin is a complex mixture of sebum oil, lipids, sweat, and environmental materials
- Synthetic sebum selected for tests

**TABLE 1—Composition of synthetic sebum (Lot #9183).**

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 %</td>
<td>Palmitic acid</td>
</tr>
<tr>
<td>5 %</td>
<td>Stearic acid</td>
</tr>
<tr>
<td>15 %</td>
<td>Coconut oil</td>
</tr>
<tr>
<td>10 %</td>
<td>Paraffin wax</td>
</tr>
<tr>
<td>15 %</td>
<td>Synthetic spermaceti</td>
</tr>
<tr>
<td>20 %</td>
<td>Olive oil</td>
</tr>
<tr>
<td>5 %</td>
<td>Squalene</td>
</tr>
<tr>
<td>5 %</td>
<td>Cholesterol</td>
</tr>
<tr>
<td>10 %</td>
<td>Oleic acid</td>
</tr>
<tr>
<td>5 %</td>
<td>Linoleic acid</td>
</tr>
</tbody>
</table>

\(^{a}\)Synthetic sebum is a product of Scientific Services S/D, Inc., 42 Main Street, Sparrow Bush, NY, 12780. (Treated to remove peroxides and flushed with nitrogen in order to prevent polymerization and oxidation; contains trace water; is stable at ambient conditions in the absence of air; nitrogen padded.)
Contamination Level Threshold

- Properties of sebum oil
  - Heat of Combustion
    - \(~39.7\) KJ/g
    - 90\% of hydrocarbon-based oil
  - Auto Ignition Temperature
    - \(139 \pm 7\) °C
    - Silicone grease AIT = 216 °C
Contamination Level Threshold

• Evaluated contamination level due to handling without gloves
  – Five technicians
  – Four separate occasions
  – “Flip & Grip” test coupons
  – NVR = 14 ± 5 mg/m\(^2\)
Contamination Level Threshold

- Rapid pressurization according to ASTM G74
- Oil coated cylindrical rods
- Varied surface concentration (9000 mg/m²)
- Tested at 4000 psi (27.6 MPa)
Detection Technique

- Sapphire View Window
- SS Modified Viewing Chamber
- SS Sleeve
- GRIN Lens
- SS B-Nut
- SS Ball Support
- Axial Nut (Sample Holder)
- Vespel SP21 Gas Cylinder

Camera
- IR Viewing Scope
- GRIN Relay Lens
- Boroscope
- Modified Viewing Chamber
- Sample Holder

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Oil Contamination by Rapid Pressurization in Oxygen Systems

Modified Viewing Chamber

IR Viewing Scope

Camera
Contamination Level Threshold

- Threshold surface concentration was 150 mg/m²
- Next highest concentration tested was 340 mg/m²
- Hand oil contamination maximum 20 mg/m²

<table>
<thead>
<tr>
<th>Contamination level (mg/m²)</th>
<th>Number of reactions/number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>9,000</td>
<td>1/3</td>
</tr>
<tr>
<td>3,200</td>
<td>1/12</td>
</tr>
<tr>
<td>540</td>
<td>1/27</td>
</tr>
<tr>
<td>340</td>
<td>1/16</td>
</tr>
<tr>
<td>150</td>
<td>0/40</td>
</tr>
</tbody>
</table>
Oxygen Pressure Level Threshold

- Rapid pressurization according to ASTM G74
  - Each sample subjected to 5 consecutive pneumatic impact events for each test data point
- Minicell L-200 polyethylene foam samples
- Contaminated with WD-40
- Tested at various oxygen pressures
Oxygen Pressure Level Threshold

- A reaction occurred at 300 psia
- No reactions occurred at 275 psia in 80 tests

<table>
<thead>
<tr>
<th>Impact Pressure (Mpa)</th>
<th>Number of Reactions</th>
<th>Number of Samples Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 350</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>2.1 300</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>2.1 300</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1.9 275</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>1.9 275</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>1.9 275</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

From WSTF Number 06-40281
Summary

- Contamination level threshold
  - Sebum (fingerprint) oil
  - 4000 psi rapid pressurization
  - Between 150 and 340 mg/ft$^2$
  - Fingerprints could contribute to other oil contamination

- Oxygen pressure level threshold
  - WD-40 oil
  - Standard rapid pressurization test system
  - Between 275 and 300 psia
  - Below 275 psia (minus your desired margin) no ignition due to rapid pressurization

Oct 2006 Tapia, Smith, Hshieh, and Stoltzfus
Pneumatic-Impact Ignition of Sebum Oil Film in High-Pressure Oxygen