Flammability, toxicity and corrosiveness of vented gas

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Principles

• Any proposed limit values should be based on applicable, recognized, international, expert consensus values

• Recognize realities of vent gas behaviors
  • Lithium ion battery vent gases are visible (i.e., “smoke”) even though certain constituents may be colorless
  • Type of venting strongly influences vent gas content
    • Low temperature – electrolyte vapor
    • Higher temperatures – products of combustion/partial combustion (proportions vary by temperature and failure mode)
An Evaluation Approach

• Used as internal evaluation method
  • Not suitable in current form as possible regulatory methodology
  • Shared for informational purposes to encourage discussion and investigation

• Requires significant assumptions
  • Detected gases are the only ones of interest
  • Perfect mixing and dispersion within enclosed passenger compartment
System / vehicle effects evaluated

- Induce single cell venting
- Collect and analyze gas content and quantity
- Estimate pack-level behavior (i.e., number of cells venting within what time period)
- Scale gas quantities to estimated pack-level outcomes
- Criteria: Does amount of vent gas exceed allowable levels?
  - Predicted number of cells venting x amount of gas/cell
  - $> \text{or}< \text{ Allowable level}$
  - Example allowable level: AEGL-2, 10 minute limit
Vent gas assessment method

Test Method

Enclosed test chamber

Gas sampling container

Analysis Method

Test Results

Carbon Dioxide

Ethane

Other

Carbon Monoxide

Hydrogen

Methane

<table>
<thead>
<tr>
<th>Chemical Species</th>
<th>Test gas phase</th>
<th>molar mass (g/mol)</th>
<th>mg/m^3</th>
<th>mg/m^3</th>
<th>AEGL 2 for 10 min (ppm)</th>
<th>AEGL 2 for 10 min (mg/m^3)</th>
<th>LFL by volume</th>
<th>% vol fraction</th>
<th>Volume of gas emitted (L)</th>
<th>% vol fraction (%)</th>
<th>g/s/L</th>
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<tbody>
<tr>
<td>Hydrogen Fluoride</td>
<td>0.991</td>
<td>20.06</td>
<td>0</td>
<td>95</td>
<td>83.7</td>
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<td>H₂</td>
<td>0.0813</td>
<td>2.016</td>
<td>0</td>
<td>4</td>
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<tr>
<td>CO₂</td>
<td>1.842</td>
<td>44.01</td>
<td>0</td>
<td>0</td>
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<tr>
<td>CO</td>
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<td>28.01</td>
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<td>420</td>
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<td>Phosphine (PH₃)</td>
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<td>3.99</td>
<td>0</td>
<td>4</td>
<td>1.79%</td>
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<td>Formaldehyde</td>
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<td>Acetaldehyde</td>
<td>956</td>
<td>44.053</td>
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<td>Propionaldehyde</td>
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<td>58.079</td>
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<td>Butyraldehyde</td>
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<td>Valeraldehyde</td>
<td>810</td>
<td>86.132</td>
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<td>Methane (CH₄)</td>
<td>0.668</td>
<td>16.043</td>
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<td>Ethane (C₂H₆)</td>
<td>1.264</td>
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<td>Ethylene (C₂H₄)</td>
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<td>Propane (C₃H₈)</td>
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<td>Propene/Propylene (C₃H₆)</td>
<td>1.748</td>
<td>1.748</td>
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<td>0.00</td>
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Challenges

• Gas collection and analysis
  • Temperature changes – condensation, volume
  • Continued reactions after collection
  • Volume estimation – ideal gas law?
  • Aerosol effects (electrolyte)
  • What to look for (gases expected impact methods used)

• Accounting for variation in gas species and amounts
  • Test to test
  • “Type” of venting

• Limits and criteria
  • Source
  • Limits for “obscure” chemicals
Example Limit Value Source
Acute Exposure Guideline Levels (AEGL)

• Initiated by U.S. National Academies
• Published by U.S. Environmental Protection Agency (https://www.epa.gov/aegl)
• The objectives of the process are:
  • Development of scientifically valid AEGL values for use in chemical emergency planning, prevention and response programs.
  • Comprehensive identification of published and unpublished information sources used to set AEGLs.
  • Sharing resource burdens by stakeholder members.
  • Adoption of consistent emergency planning both domestically and internationally.
  • Transparency of program methods (Standard Operating Procedures or SOPs) and information through public participation at meetings and by commenting on Federal Register notices.
  • Inclusion of National Academies (formerly National Academy of Science [NAS]) as the final peer reviewer of AEGL values and methods.
Acute Exposure Guideline Levels (AEGL)

• Currently have values for 272 chemicals
  • Final: 176
  • Interim: 84
  • Proposed: 12

• Structure of Limits
  • Up to 15 different levels
  • Effects:
    • Level 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
    • Level 2: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
    • Level 3: Life-threatening health effects or death.
  • Exposure Times:
    • 10 min, 30 min, 60 min, 4 hr, 8 hr