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

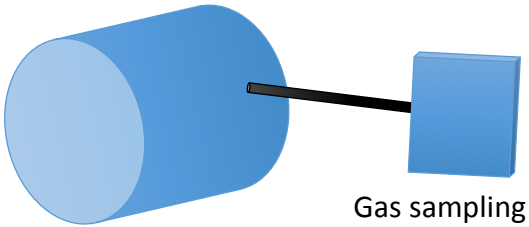
- Requires significant assumptions
  - Detected gases are the only ones of interest
  - Perfect mixing and dispersion within enclosed passenger compartment

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
  - *> or <* Allowable level
  - Example allowable level: AEGL-2, 10 minute limit

Vent gas assessment method

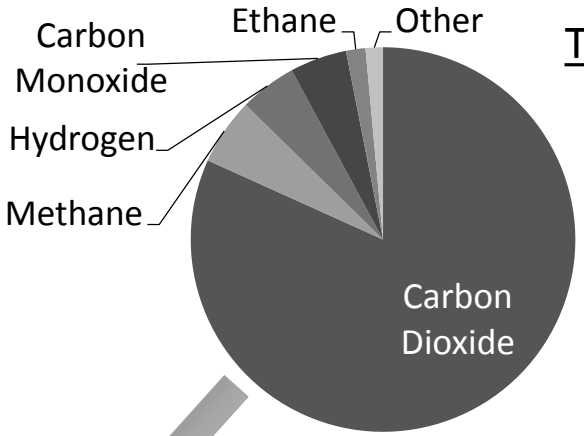
Test Method



Enclosed test chamber

Gas sampling container

Test Results



Analysis Method

Chemical Species	Gas properties: ρ (NTP)	units	molar mass (g/mol)	Emissions /cell	Select emission units	Select elevation (km)	Vehicle mg/m^3	Garage mg/m^3	Criteria: AEGL 2 for 10 min (ppm)	AEGL 2 for 10 min (mg/m^3)	LFL by volume	Vehicle* Cells required to surpass AEGL limit (ppm)	Garage* Cells required to surpass AEGL limit (ppm)	Gas Mixture Calculation: Volume of gas emitted (L)	% vol fraction (xi) of gas emitted	xi/LFLi
Hydrogen Fluoride	0.991	g/L	20.06		mg	0			95	83.7						
H2	0.0813	kg/m^3	2.016		ml	0					4%					0.00
CO2	1.842	kg/m^3	44.01		ml	0										
CO	1.165	kg/m^3	28.01		ml	0			420		12%					0.00
Phosphine (PH3):	1.379	kg/m^3	34		ug	0			4	5.99	1.79%					0.00
Formaldehyde:	1090	kg/m^3	30.026		ug	0			14	18.5	7.0%					0.00
Acetaldehyde:	956	kg/m^3	44.053		ug	0			340	659	4.0%					0.00
Propionaldehyde:	805	kg/m^3	58.079		ug	0			330	844	2.9%					0.00
Butyraldehyde:	800	kg/m^3	72.106		ug	0					2.5%					0.00
Valeraldehyde:	810	kg/m^3	86.132		ug	0					2.1%					0.00
Methane (CH4):	0.668	kg/m^3	16.043		ml	0					5.0%					0.00
Ethane (C2H6):	1.264	kg/m^3	30.07		ml	0					3.0%					0.00
Ethylene (C2H4):	1.138	kg/m^3	28.05		ml	0					2.75%					0.00
Propane (C3H8):	1.882	kg/m^3	44.09		ml	0			17000		2.1%					0.00
Propene/Propylene (C3H6):	1.748	kg/m^3	1.748		ml	0					2.0%					0.00
n-Butane (C4H10):	2.489	kg/m^3	58.1		ml	0			24000		1.86%					0.00

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