SAND2019-4309C

Modeling of Ventilation Strategies for CNG Vehicles

PRESENTED BY

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Overview

Computational Fluid Dynamics (CFD) Modeling of a CH_4 leak in a garage

Previously looked at different leak sizes, CNG vs LNG

Papers and video at: altfuels.sandia.gov

Current work: Effect of ventilation on same leak

Building off of same study for a H_2 car

Light Duty Vehicle Maintenance Garages: Garage Layout

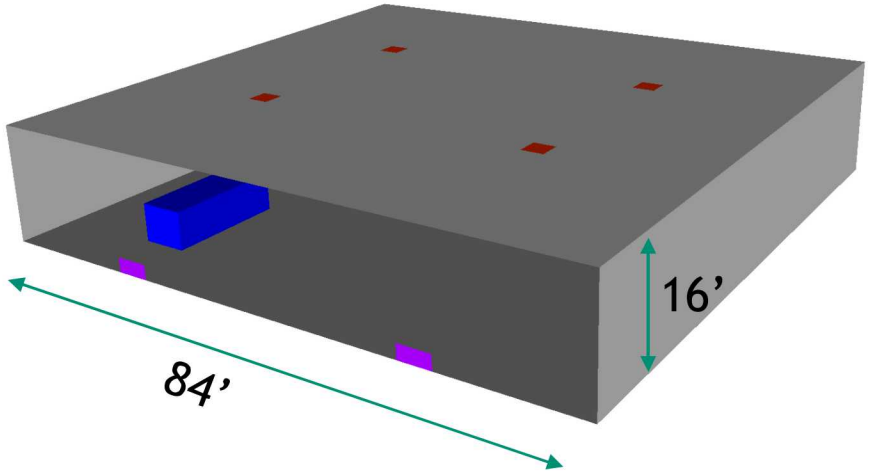
12 bays with aisle – medium/large size facility

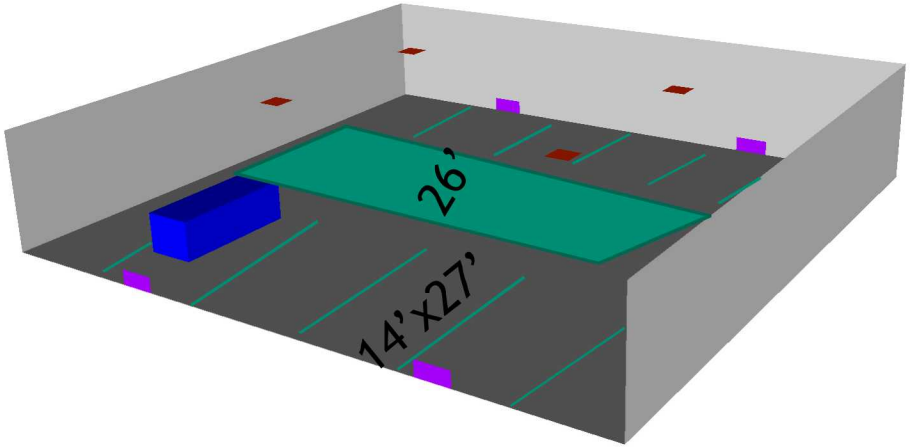
4 floor inflow vents

4 ceiling outflow vents

No other equipment

Item	Width	Length	Height
Vents in	4.5’	--	2’
Vents out	3’	3’	--
Car	6’	16’	5’





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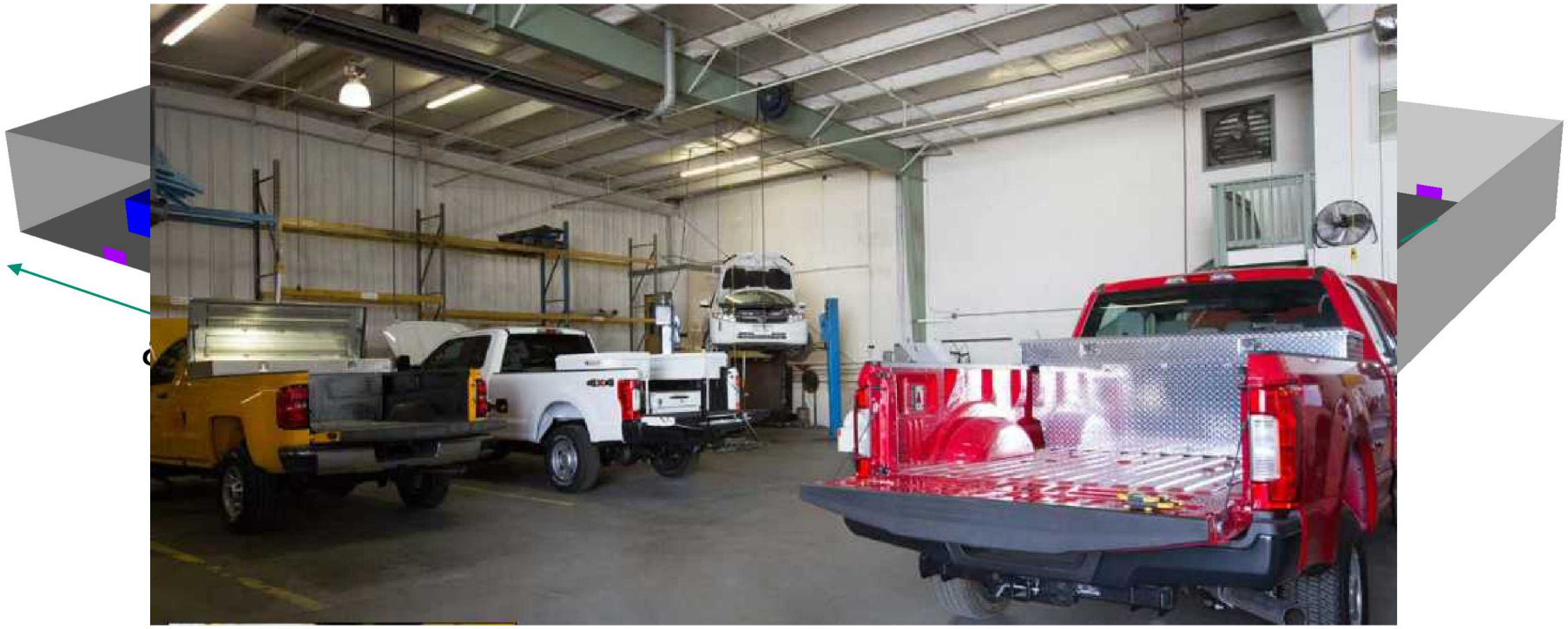
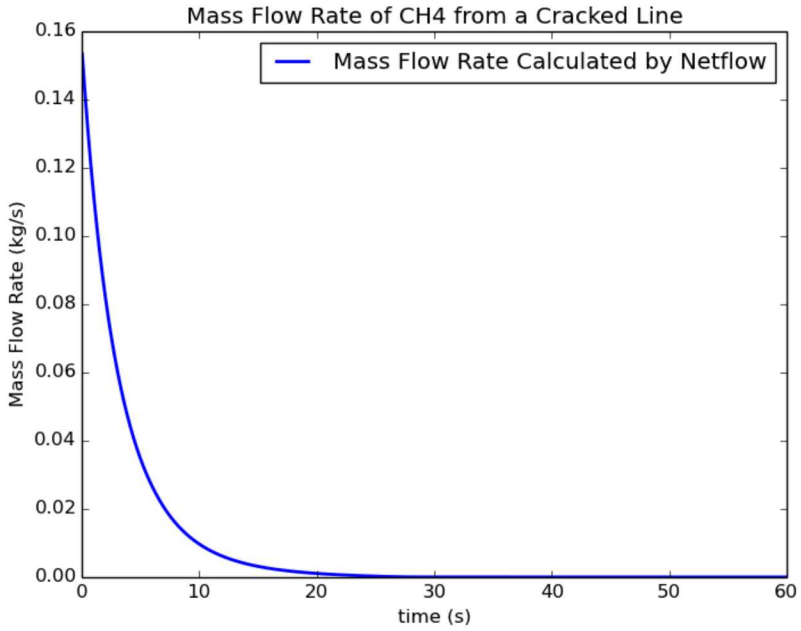


Picture source: Kelly & Melendez, 2017

Leak Description

Likely light duty vehicle leak from a cracked line.

- 3.3 liters @ 248 bar;
- Size of hole is 3% by area of 1.27 cm ID tubing



Vehicle on jack 2' off floor, leak is downward

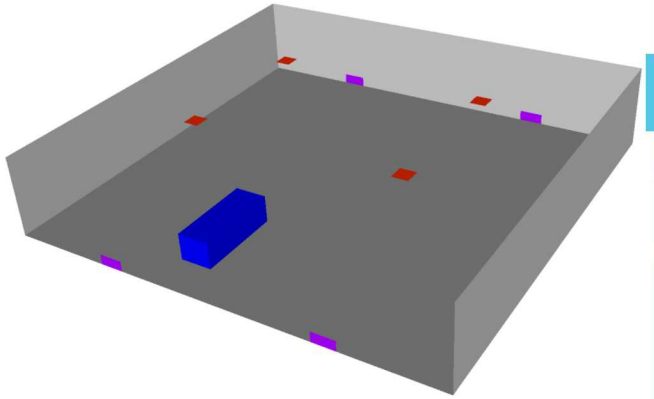
Gas in the flammable range: 5-15% by volume

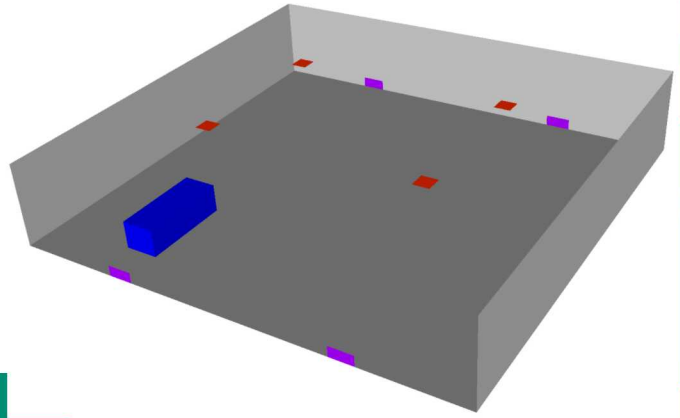
Integrated over the volume to get flammable mass.

Ventilation

Five ventilation scenarios

1. No ventilation
2. Standard ventilation: leak away from inflow
3. Standard ventilation: leak near inflow
4. Box fan continuously going
5. Box fan starting at same time as the leak

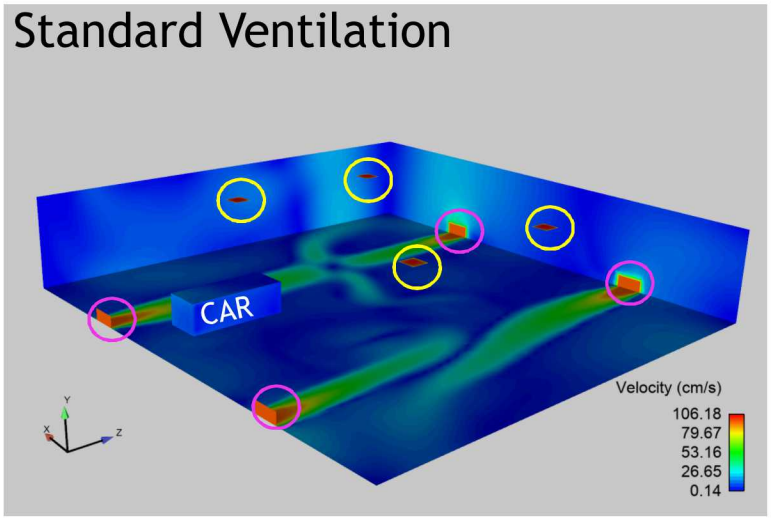




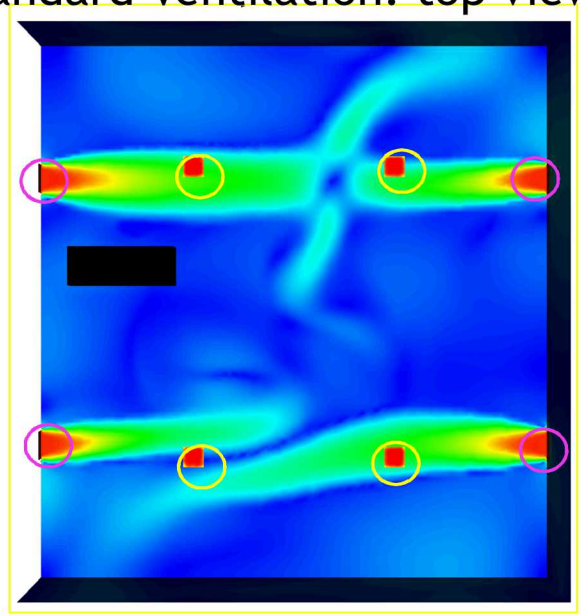
Code Requirements	Regulation equation	Vent velocity $\left[\frac{cm}{s}\right]$
NFPA 30A 7.3.6.7: H_2 repair facility 1 cfm/ft²	$\frac{\dot{V}}{A_{floor}} = 1\frac{ft^3}{min * ft^2}$	94.8
IFC 2311.8: 1 cfm per 12 ft³	5 air flow changes per hour	125.9
Standard repair facility 0.75 cfm/ft²	$\frac{\dot{V}}{A_{floor}} = 0.75\frac{ft^3}{min * ft^2}$	71.1
Box fan	N/A	300.0

Garage Ventilation

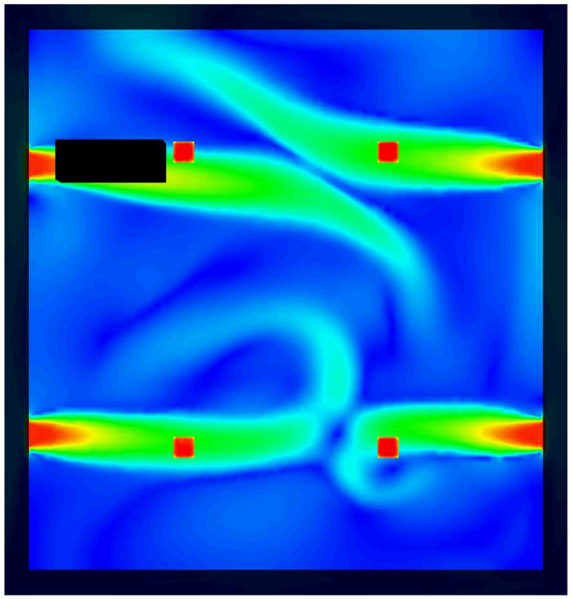
Standard Ventilation



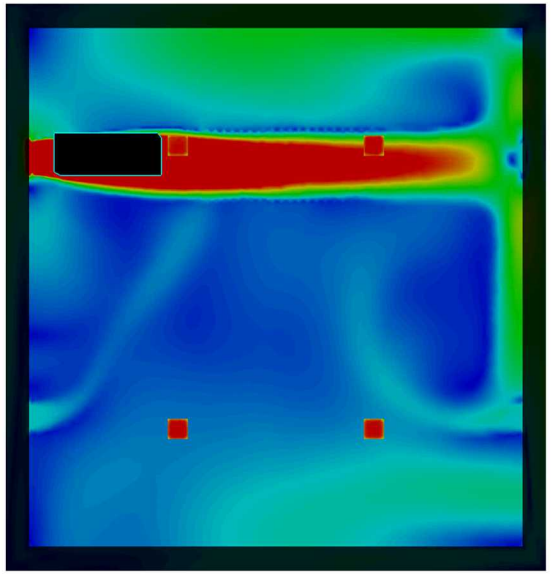
Standard Ventilation: top view



Velocity (cm/s)
100.00
75.00
50.00
25.00
0.00



Standard Ventilation: leak near inflow

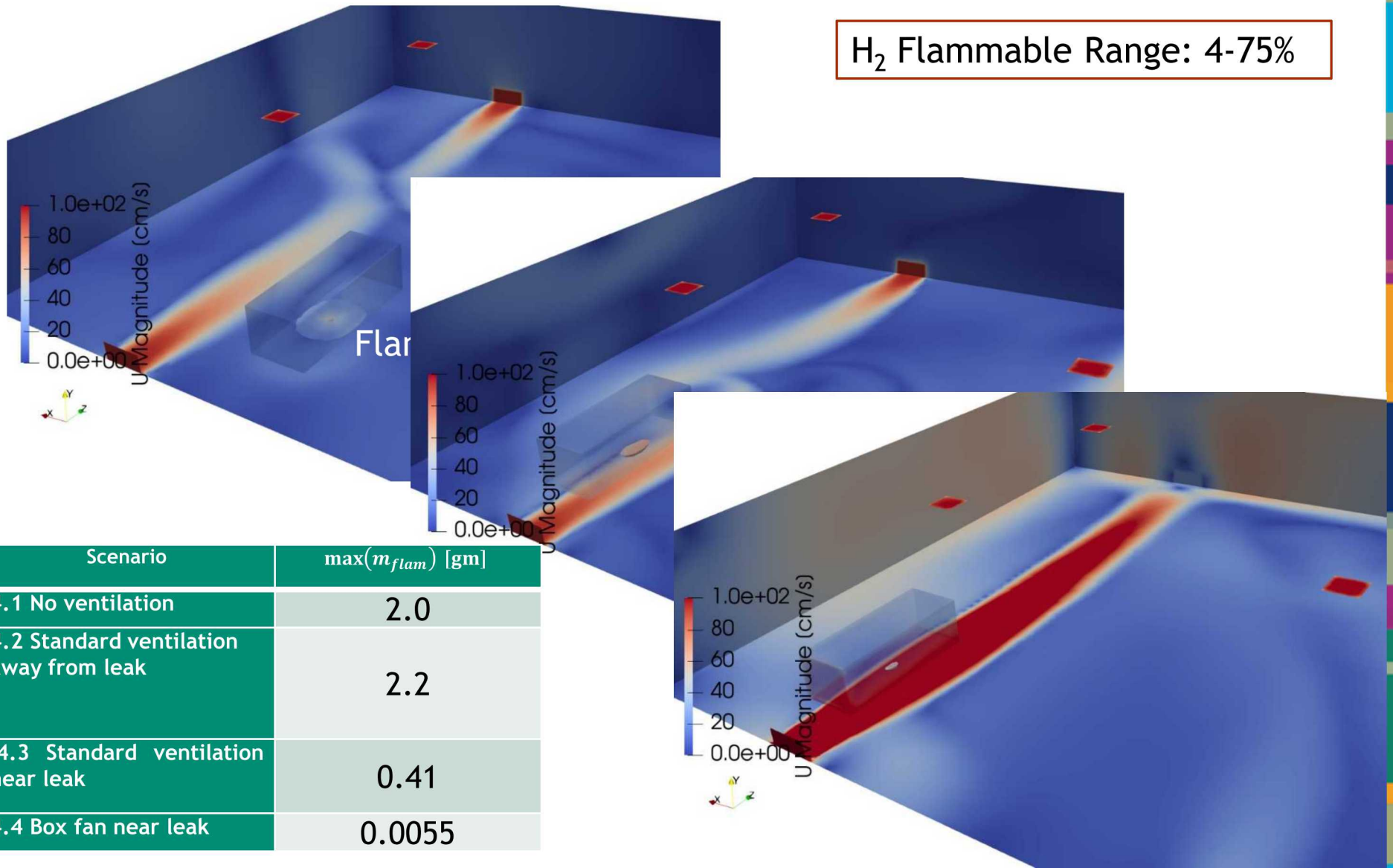


Box Fan Ventilation

Hydrogen Fuel Cell Car

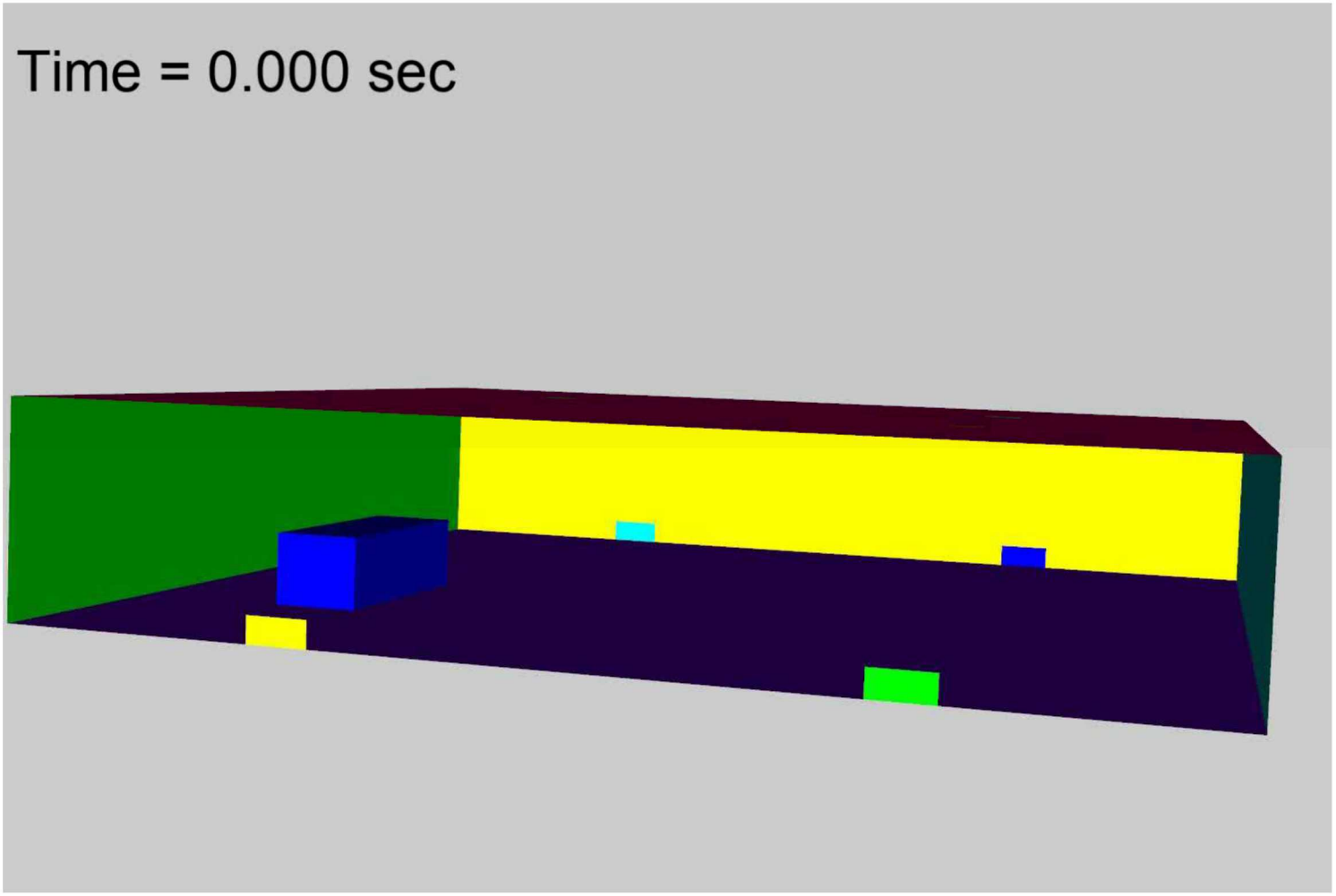
Less flammable mass when closer to ventilation or with more ventilation.

H_2 Flammable Range: 4-75%



Scenario	$\max(m_{flam})$ [gm]
4.1 No ventilation	2.0
4.2 Standard ventilation away from leak	2.2
4.3 Standard ventilation near leak	0.41
4.4 Box fan near leak	0.0055

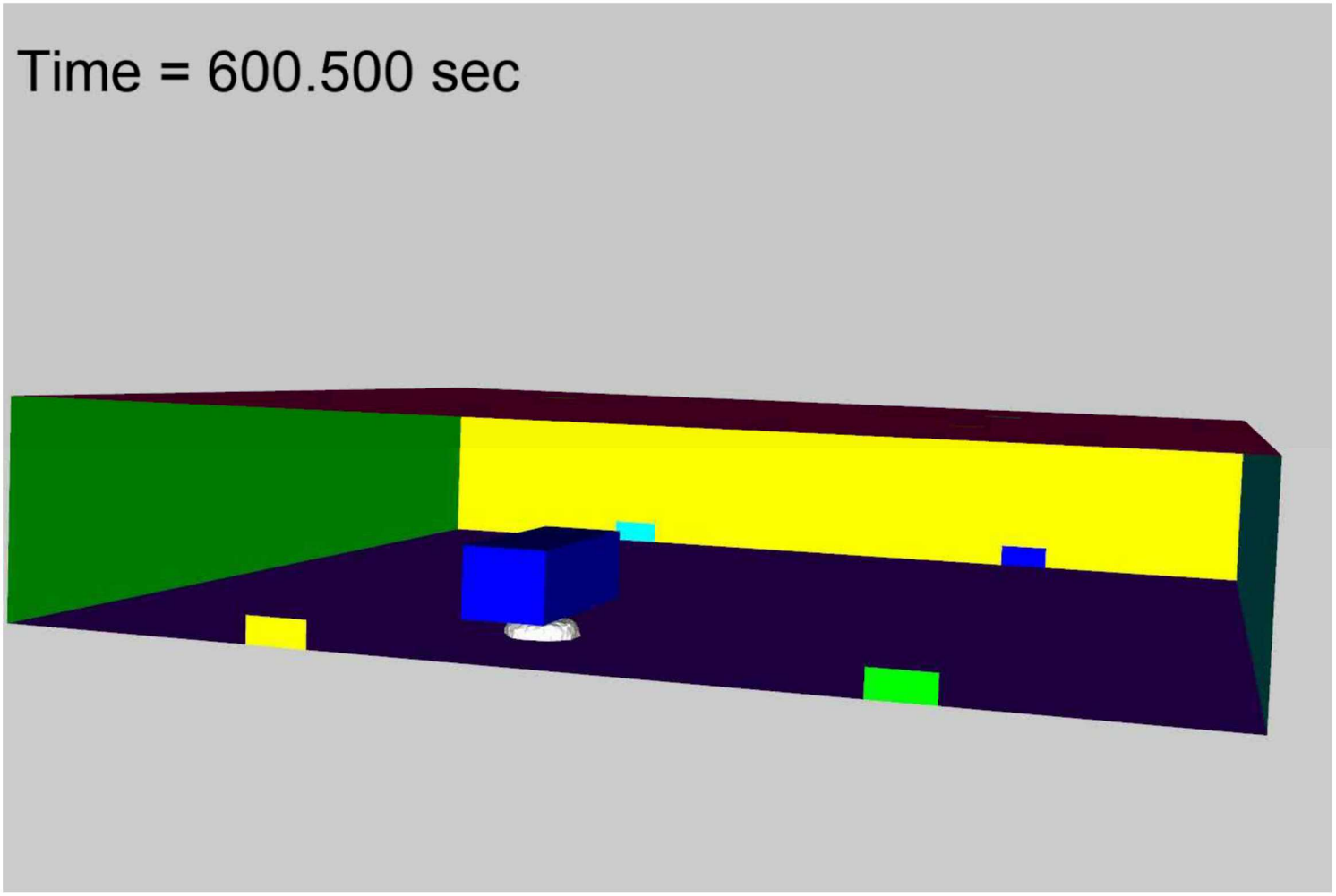
CNG Leak: No Ventilation



Maximum Flammable Mass: 140 gm

Time for dissipation: 138 sec

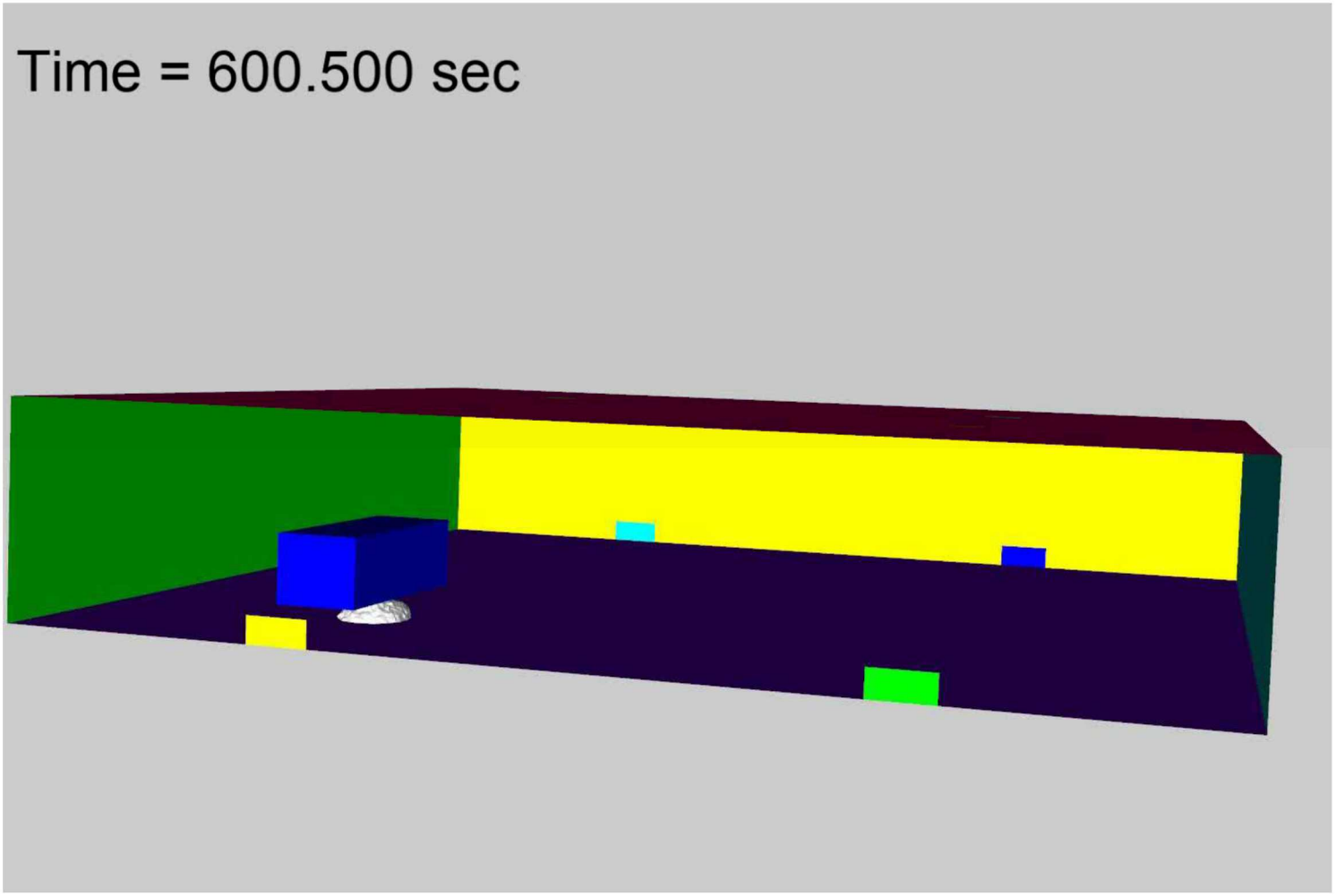
Standard ventilation with leak away from inflow ventilation



Maximum Flammable Mass: 130 gm

Time for dissipation: 103 sec

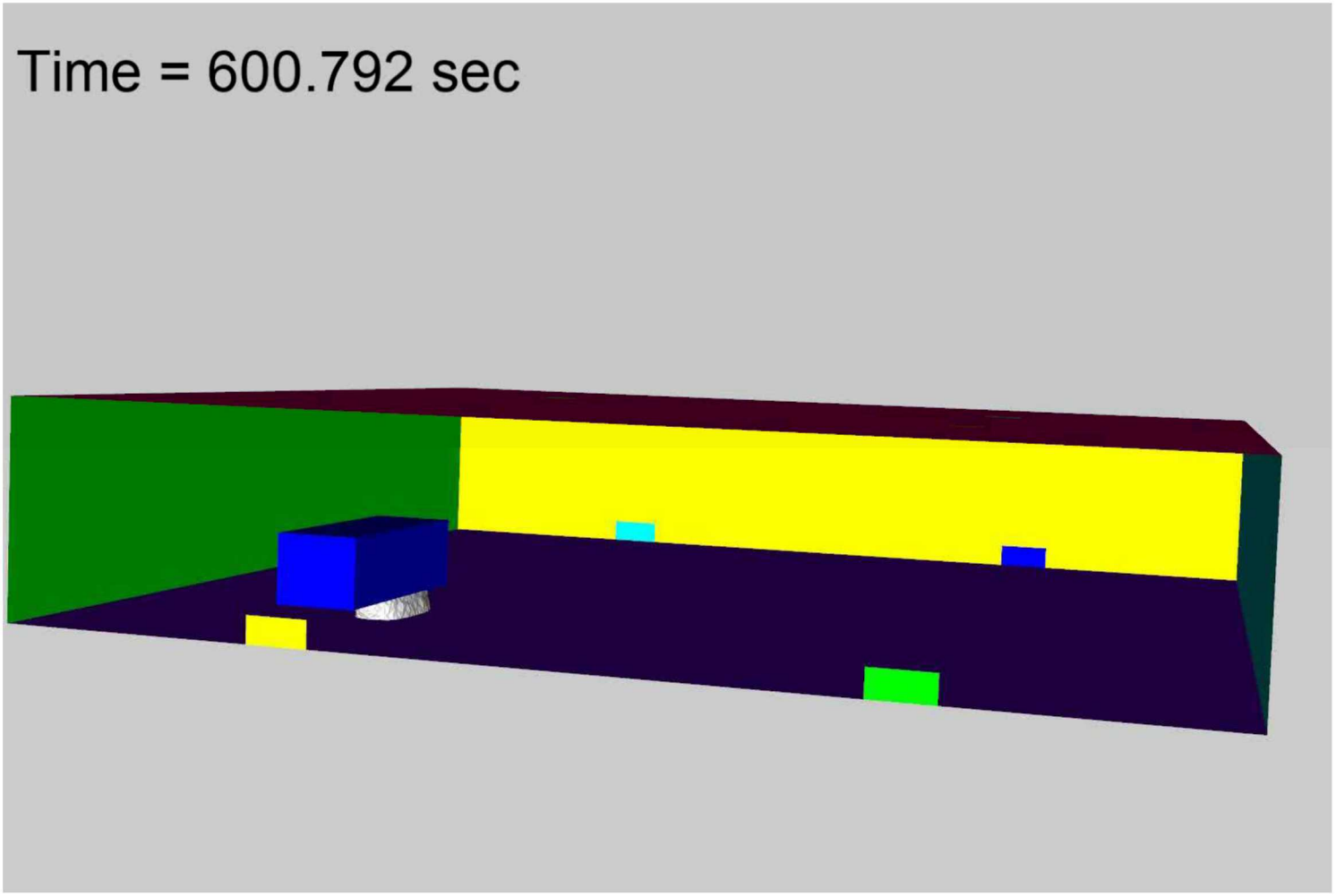
Standard ventilation with leak near inflow ventilation



Maximum Flammable Mass: 240 gm

Time for dissipation: 33 sec

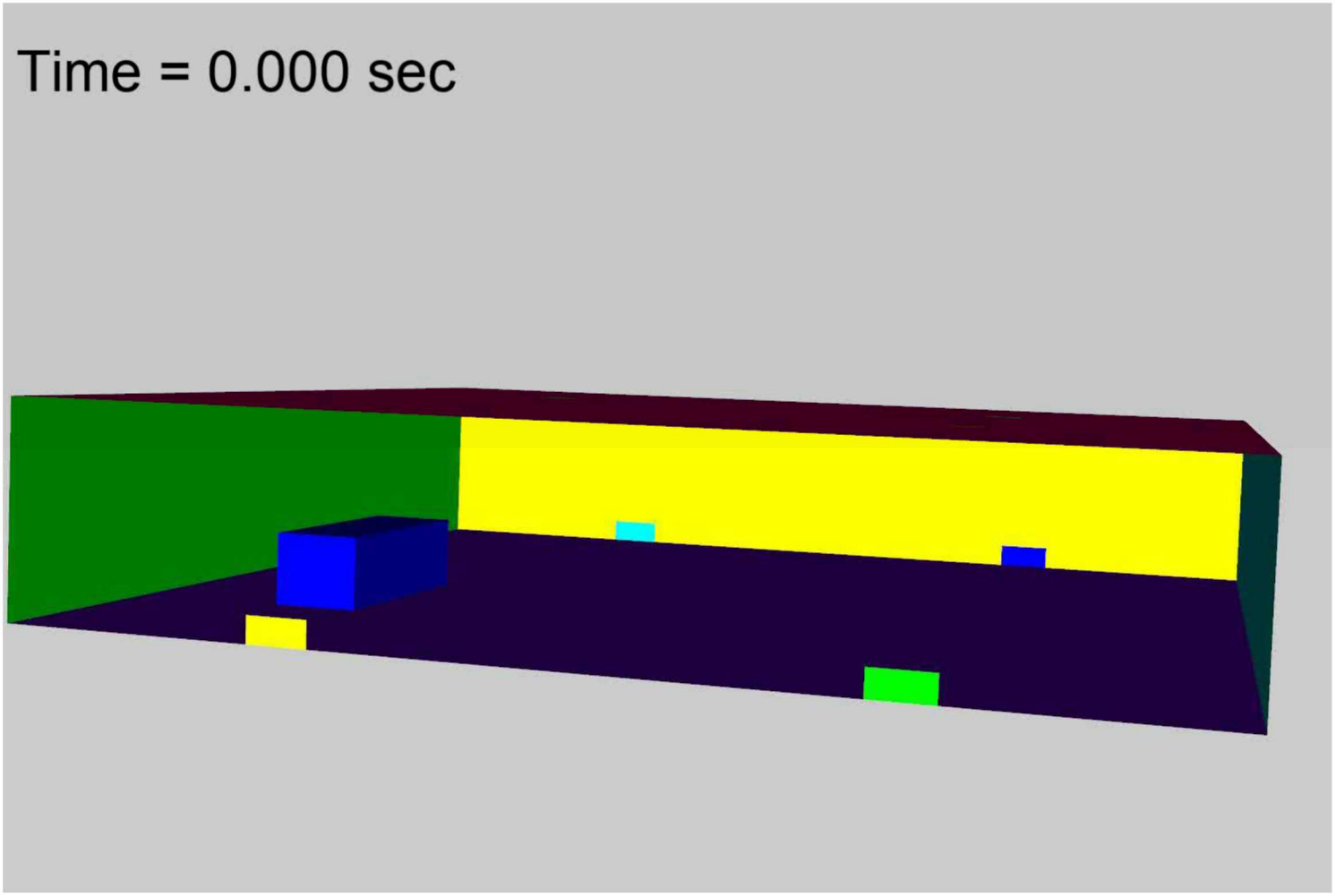
Box fan near leak – continuously going



Maximum Flammable Mass: 140 gm

Time for dissipation: 27 sec

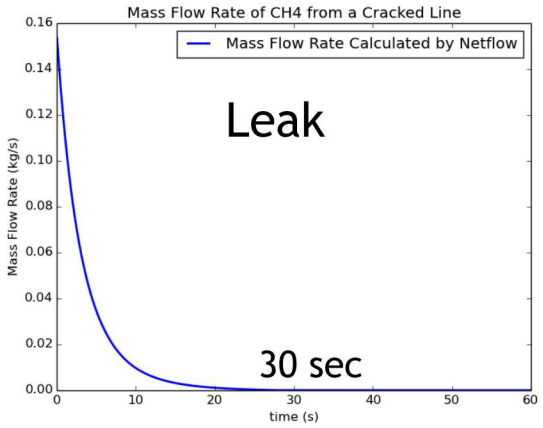
Box fan near leak – starting with "sensor"



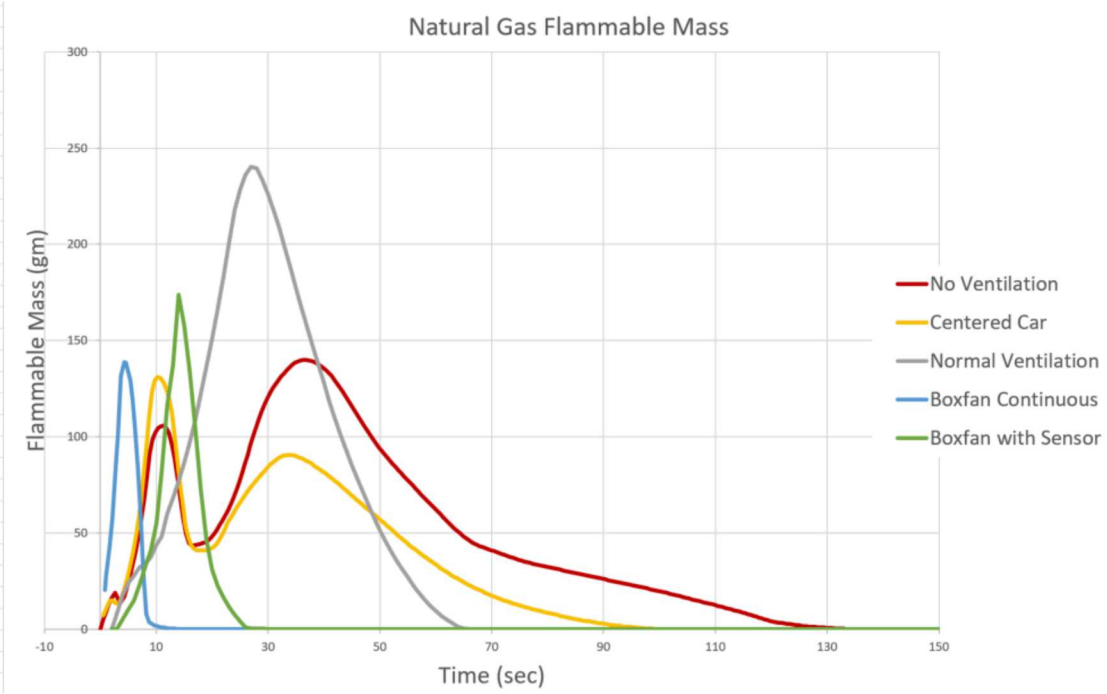
Maximum Flammable Mass: 174 gm

Time for dissipation: 27 sec

Ventilation Comparisons



	Maximum Flammable Mass	Time for Dissipation
No ventilation	140 gm	138 sec
Away from inlet	130 gm	103 sec
Near inlet	240 gm	33 sec
Box fan –continuous	140 gm	27* sec / 10 sec
Box fan - sensor	174 gm	27 sec



Conclusions

Ventilation location and amount has an effect on amount and duration of flammable mass.

Can comply with codes and not reduce risk.

Easy, non-structural changes (i.e. box fan with critical placement) might be effective.

Some NG releases can produce flammable mass that is more dense than air (for a short time).

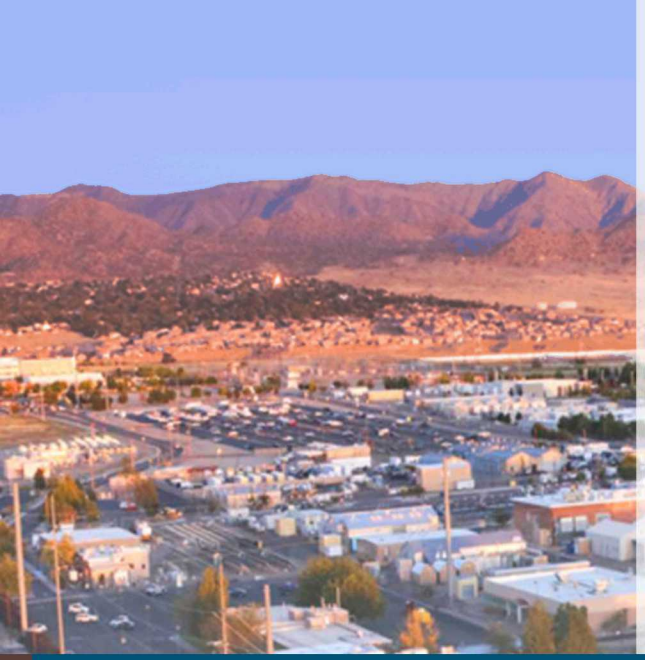
Results are different from hydrogen fuel cell vehicle simulations.

Acknowledgements

Shaun Harris – intern on hydrogen project

Brian Ehrhart, Alice Muna, Chris LaFleur

VTO Clean Cities: Dennis Smith and Mark Smith



Thank you!

Questions? Feedback?

Flammable volume of NG can be used to determine potential facility overpressure hazard

Flammable mass : Cumulative fuel mass mixed into flammable concentrations (mixtures between 5% and 15% by volume for NG-air)

$$\Delta p = p_0 \left\{ \left[\frac{V_T + V_{NG}}{V_T} \frac{V_T + V_{stoich}(\sigma - 1)}{V_T} \right]^{\gamma} - 1 \right\}$$

C. R. Bauwens, S. Dorofeev, Proc. ICHS, 2013.

p_0: Ambient pressure
V_T: Facility volume
V_{NG}: Expanded volume of pure NG
V_{stoich}: Stoichiometric consumed NG volume
σ: Stoichiometric NG expansion ratio
γ: Air specific heat ratio (1.4)

	Maximum Flammable Mass	Time for Dissipation	Maximum Overpressure
No ventilation	140 gm	138 sec	0.69 kPa
Away from inlet	130 gm	103 sec	0.64 kPa
Near inlet	240 gm	33 sec	1.19 kPa
Box fan	140 gm (174 gm)	27 sec	0.69 kPa (0.86 kPa)

Potential Consequences:

- 1 kPa: Breaks glass
- 6.9 kPa: Injuries due to projected missiles
- 13.8 kPa: Fatality from projection against obstacles
- 13.8 kPa: Eardrum rupture
- 15-20 kPa: Unreinforced concrete wall collapse

American Institute of Chemical Engineers, 1998.

— Local blast waves not considered

Mass flow rate vs velocity of leak

Mass flow rate is correct

Velocity of leak is modeled slower than 3% leak size would be due to modeling restricitions.