

REINHOLD ENVIRONMENTAL Ltd.



**2013 Coal to Gas Conversion Round Table  
& Expo Presentation**

October 29, 2013, in Chattanooga, TN / Sponsored by Southern Company

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# Gas Accumulation Potential & Leak Detection when Converting to Gas

Coal to Gas / PCUG Conference  
Chattanooga, TN  
October 29, 2013

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Airflow Sciences  
Corporation



# Introduction

- **Coal to gas conversion - safety concerns**

- Gas leak within plant can result in explosive concentration
- Build up of gas can occur if ventilation is inadequate
- Older coal plants are not necessarily well-ventilated
- Monitors need to be present to detect leaks before an accident happens
- Reaction plan has to be devised to deal with potential leaks

- **Case study - background**

- Conversion of up to 5 boilers (~50 MW)
- Site testing for gas dispersion not practical
- Design requirement is to proactively consider and design for potential leaks

- **Methodology**

- Field testing to assess current ventilation
- Computational Fluid Dynamic (CFD) flow modeling of boiler internal flow patterns
- Simulate gas leaks and worst case scenarios
- Design ventilation system, identify monitor locations, test out the reaction plan



# Design Process

## I. Natural Gas Properties -> Ventilation Criteria

- A) Buoyancy vs. air.
- B) Lower explosive limit (LEL).

## I. Leak Characterization and Detection.

- A) Leak locations (failure mode).
- B) Leak size (flow rate) estimation.
- C) Detection level.
- D) Sensor placement.

## I. Ventilation Considerations.

- A) Fan placement.
- B) Vent placement.
- C) Temperature management.

## I. Reaction Planning.

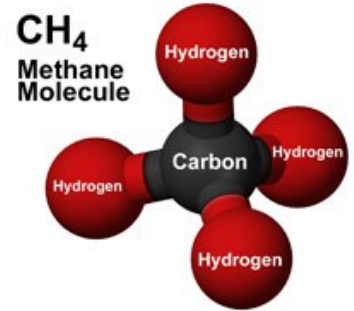
- A) System automation.
- B) Reaction sequence.



# Natural Gas Properties

- **Composition:**

- Varies by source.
- 90-100% Methane and Ethane mixture ( $\text{CH}_4$ ,  $\text{C}_2\text{H}_6$ ).
- Simulate as 100% Methane ( $\text{CH}_4$ )

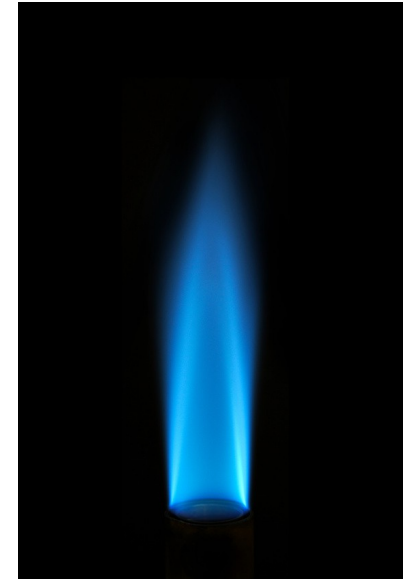


- **Buoyancy vs. Air:**

- Molecular weight 16-18 vs. 28 for air (g/mol).
- Natural gas rises.

- **Flammability Limits:**

- Methane lower explosive limit (LEL) = 5% volume fraction (2.8% mass fraction).
- Ignition may occur above this concentration if a source is present!



# Leak Characterization and Detection

## ● Leak Locations:

- Determine potential failure modes and locations.
- Flex hoses, burners, unions, etc.
- Where is a leak likely to occur?
- Where is the worst place for a leak to occur?



## ● Leak Size Estimation:

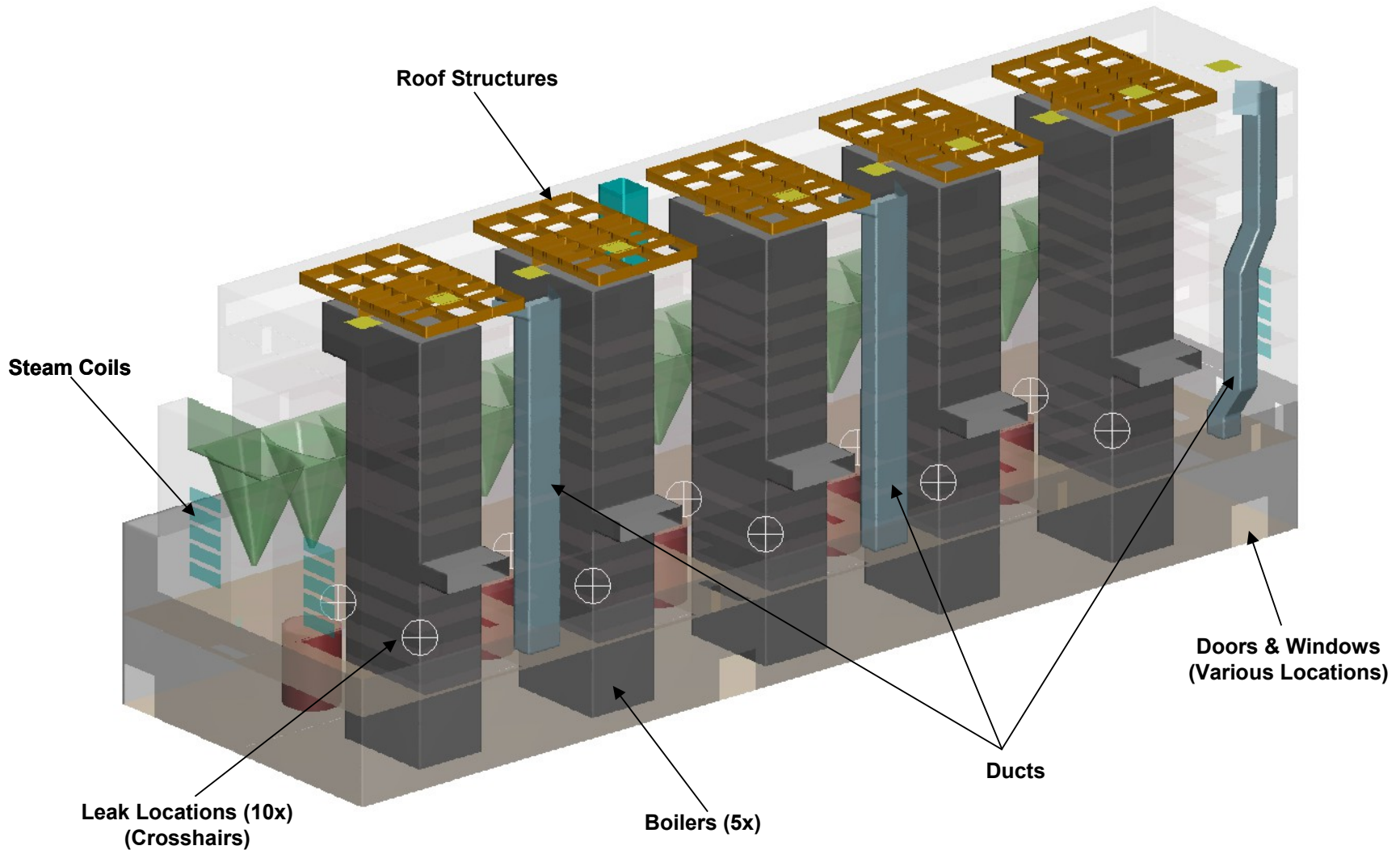
- Estimate leak flow rates based on line typical line pressures, hole/gap sizes, etc.
- Orifice-type (sonic limit) handbook calculations.

## ● Detection Limits and Sensor Placement:

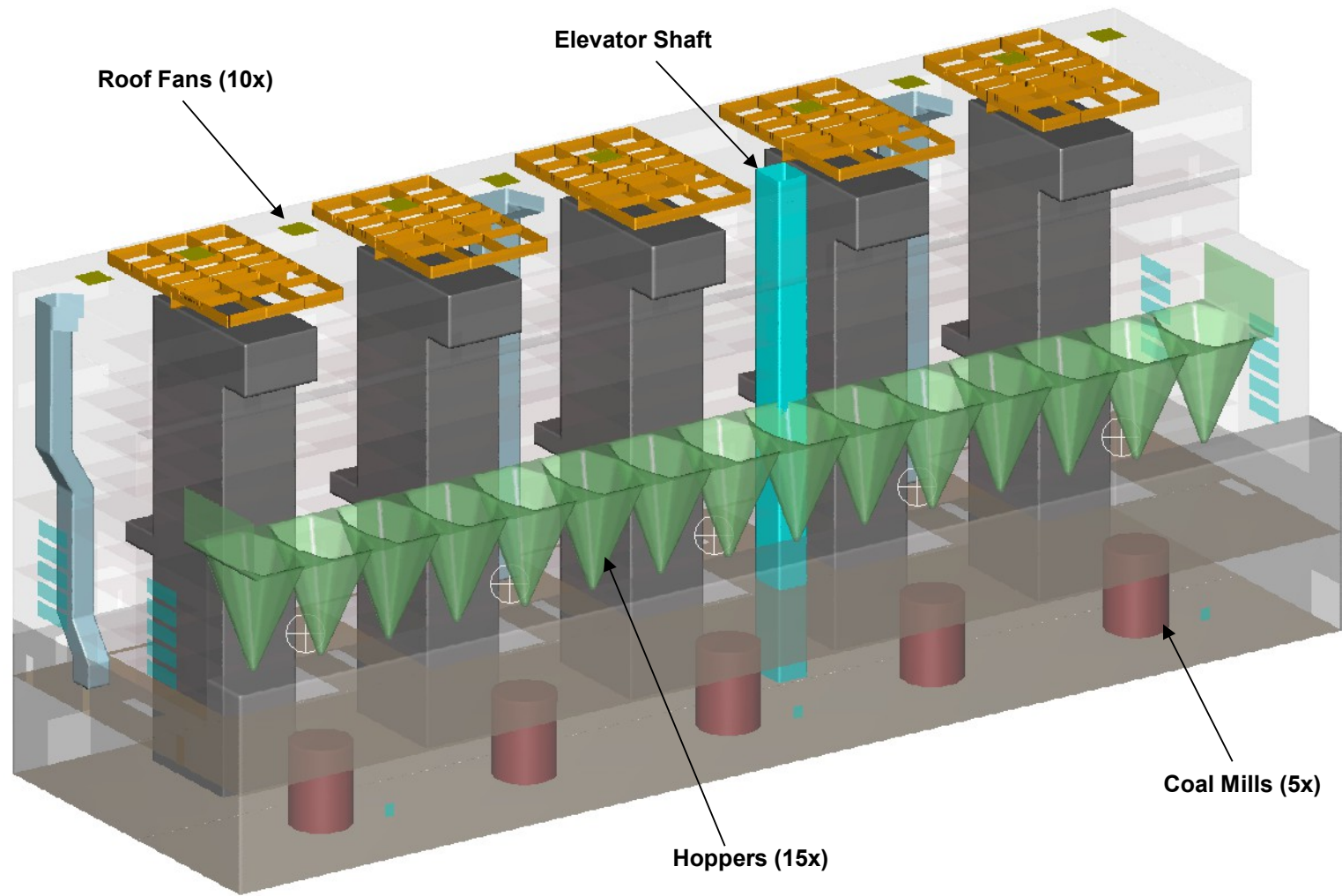
- Detect and alarm at some fraction of LEL.
- Where to place sensors for early / critical detection?



# Case Study – Geometry Overview

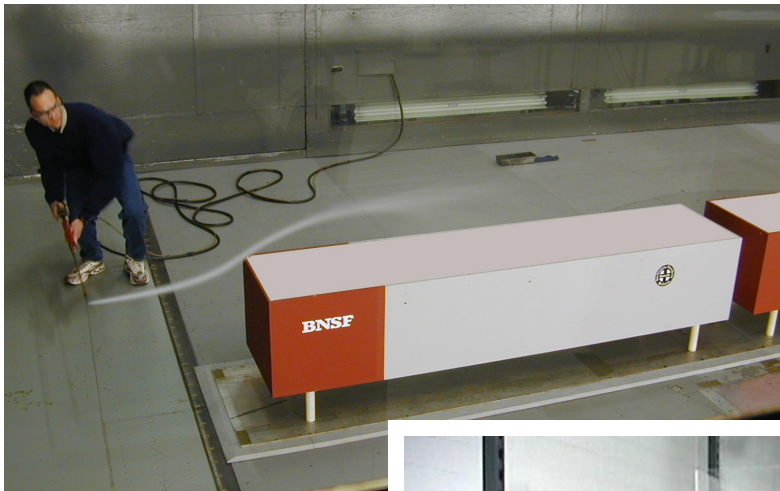


# Case Study – Geometry Overview



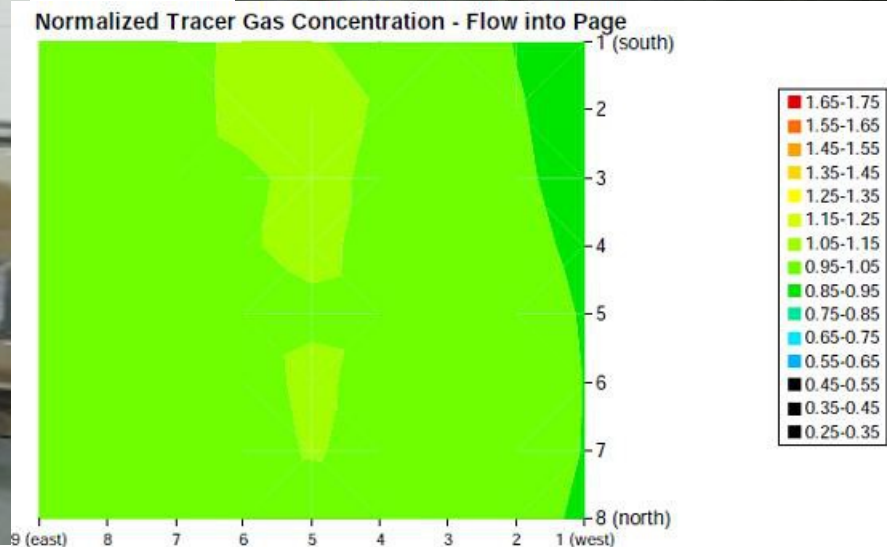
# Flow Modeling Basics

- **Physical Flow Modeling**
  - Laboratory scale models
  - Wind tunnel testing



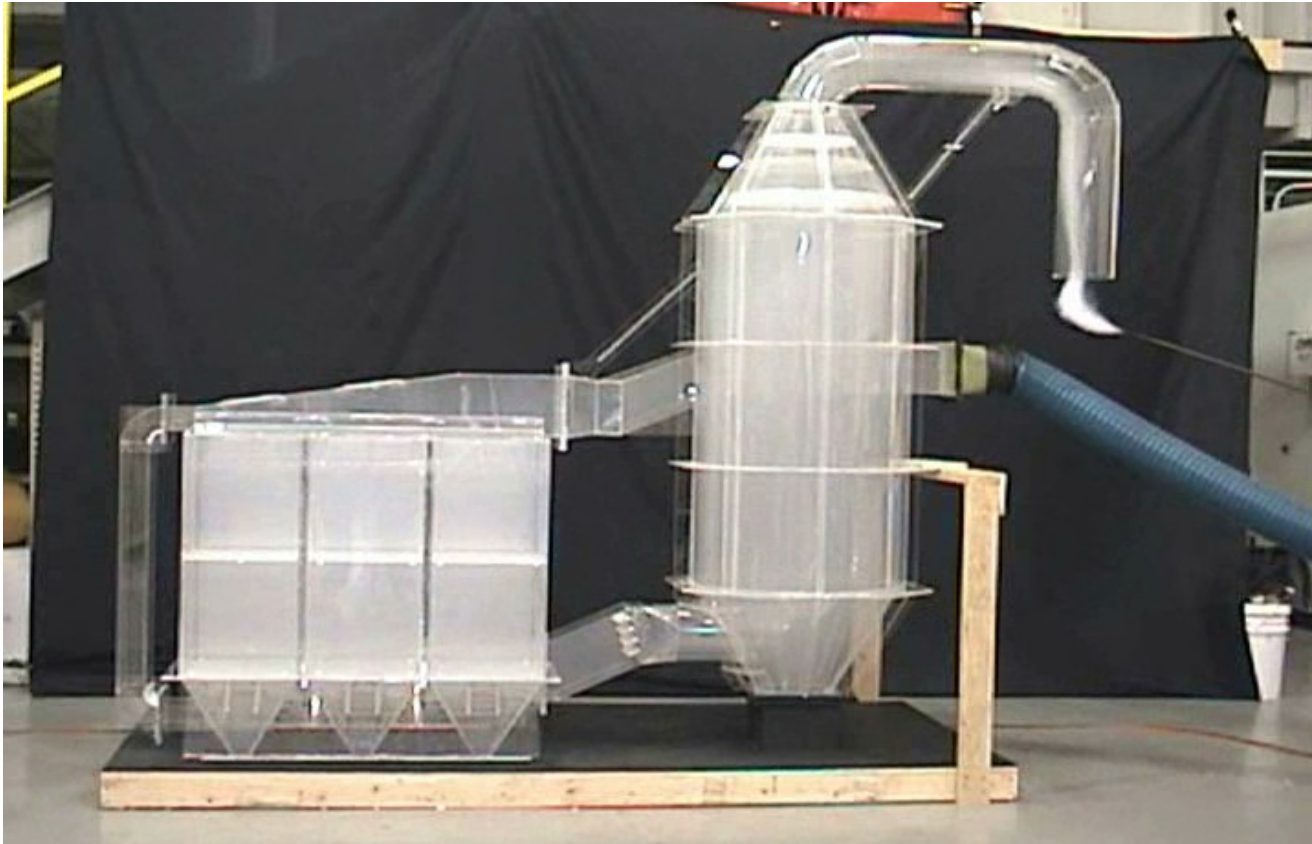
# Physical Modeling Species Tracking

- Tracer gas (quantitative)
- Smoke visualization (qualitative)



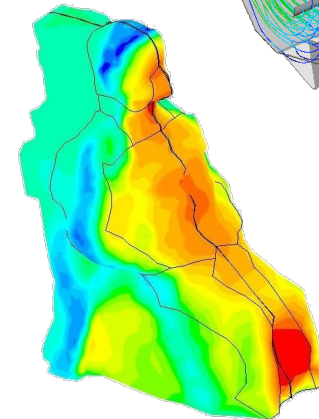
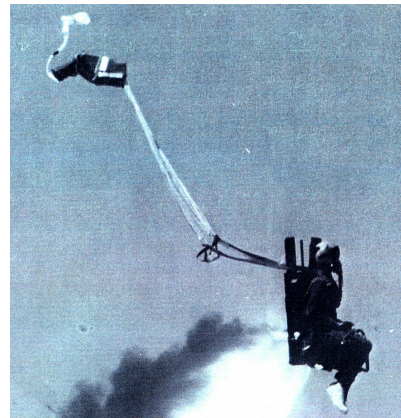
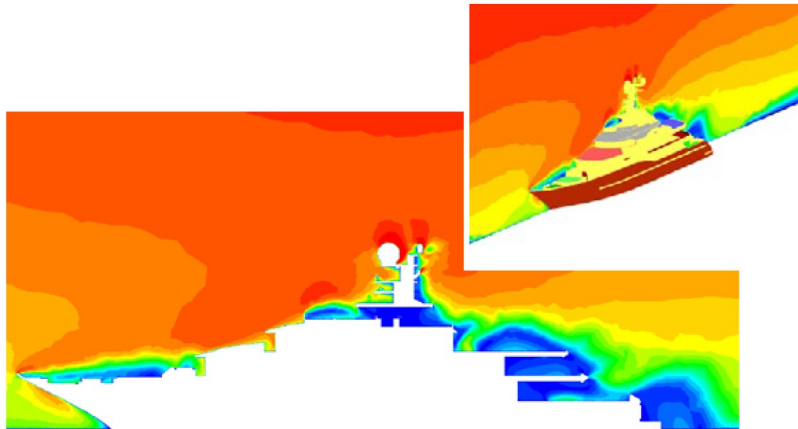
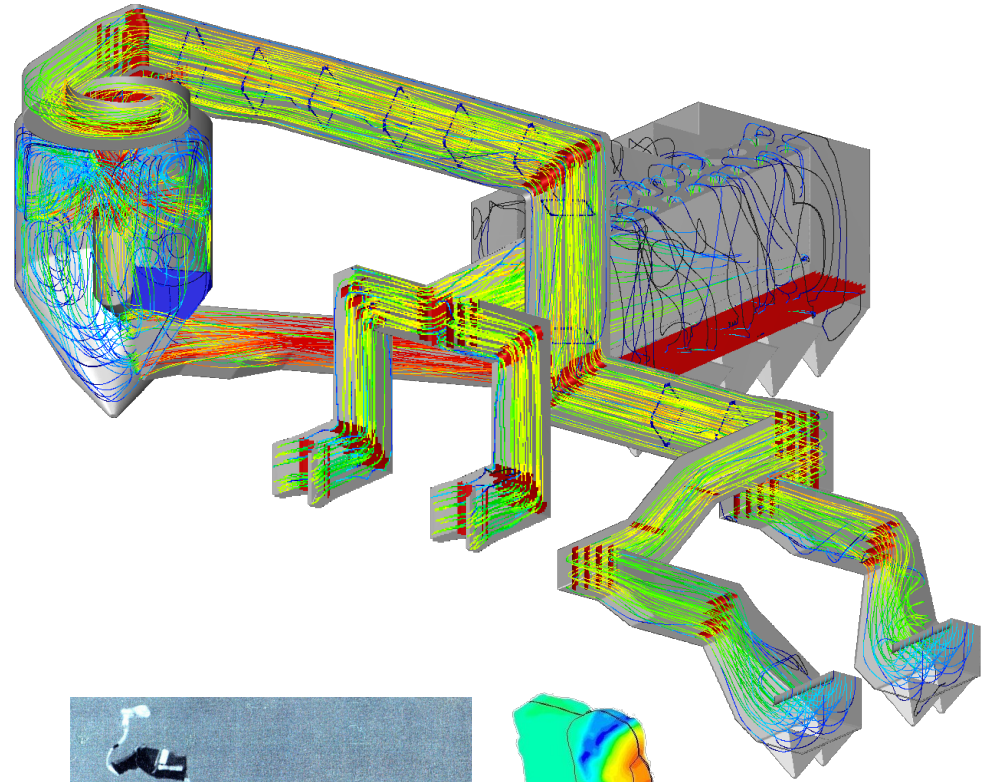
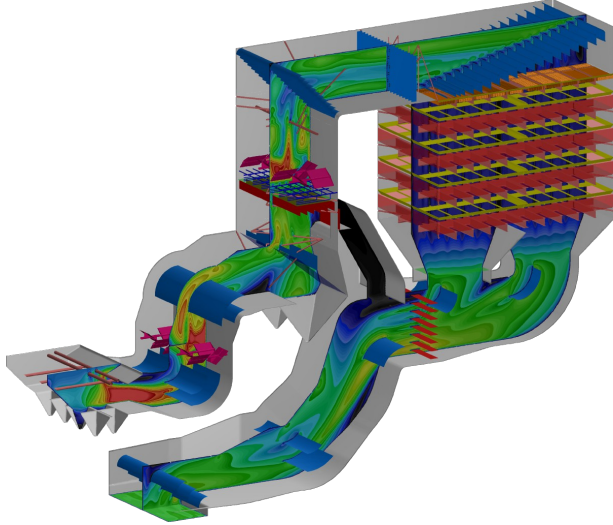
# Physical Modeling Species Tracking

- Tracer gas (quantitative)
- Smoke visualization (qualitative)



# Flow Modeling Basics

- **CFD Flow Modeling**
  - Virtual models
  - Complex physics



# CFD Modeling Species Tracking

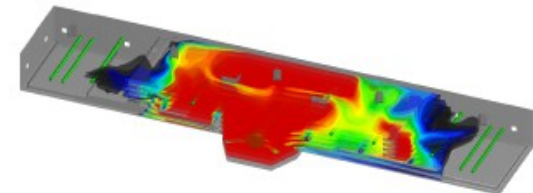
- Concentration plots (quantitative)
- Flow animations (qualitative)



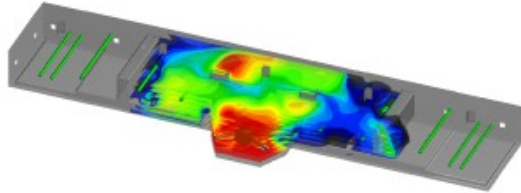
t = 141sec.



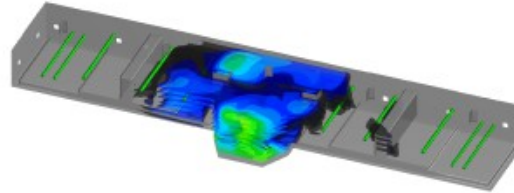
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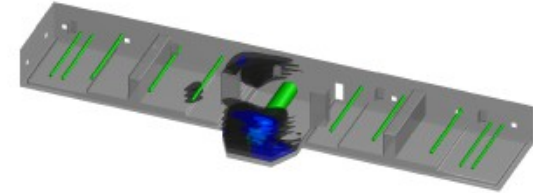
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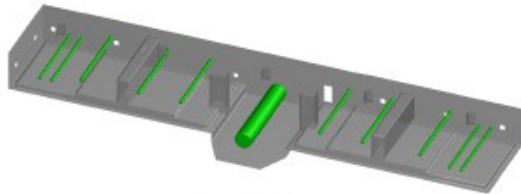
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t = 705sec.



t = 846sec.

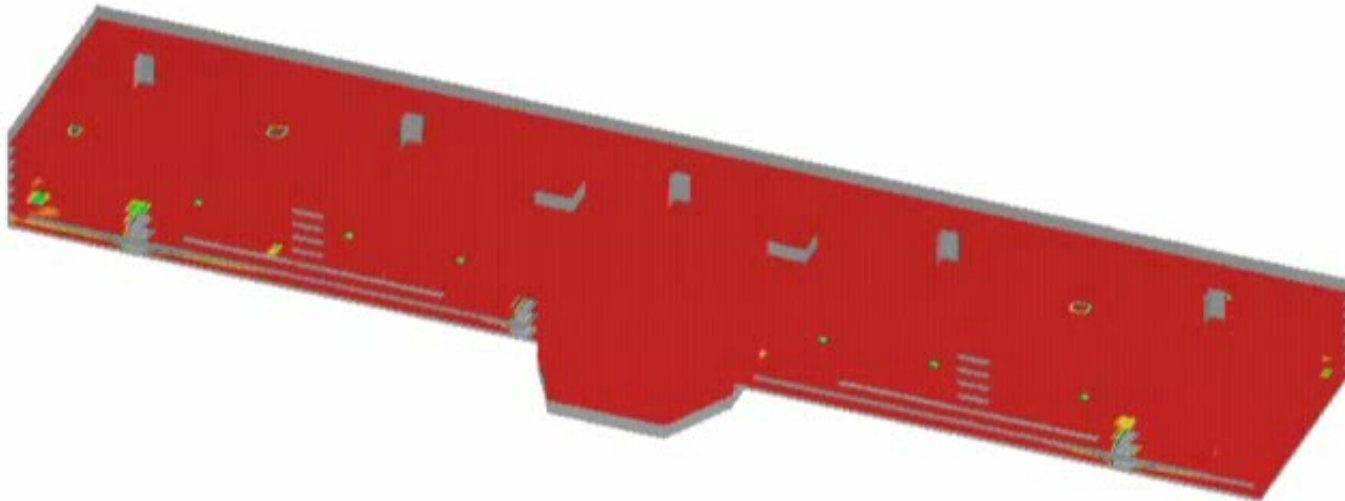


t = 987sec.

# CFD Modeling Species Tracking

- Concentration plots (quantitative)
- Flow animations (qualitative)

Design 07: Transient Venting Analysis, 25000 cfm  
Contours of Mass Fraction N<sub>2</sub> > 1.7%



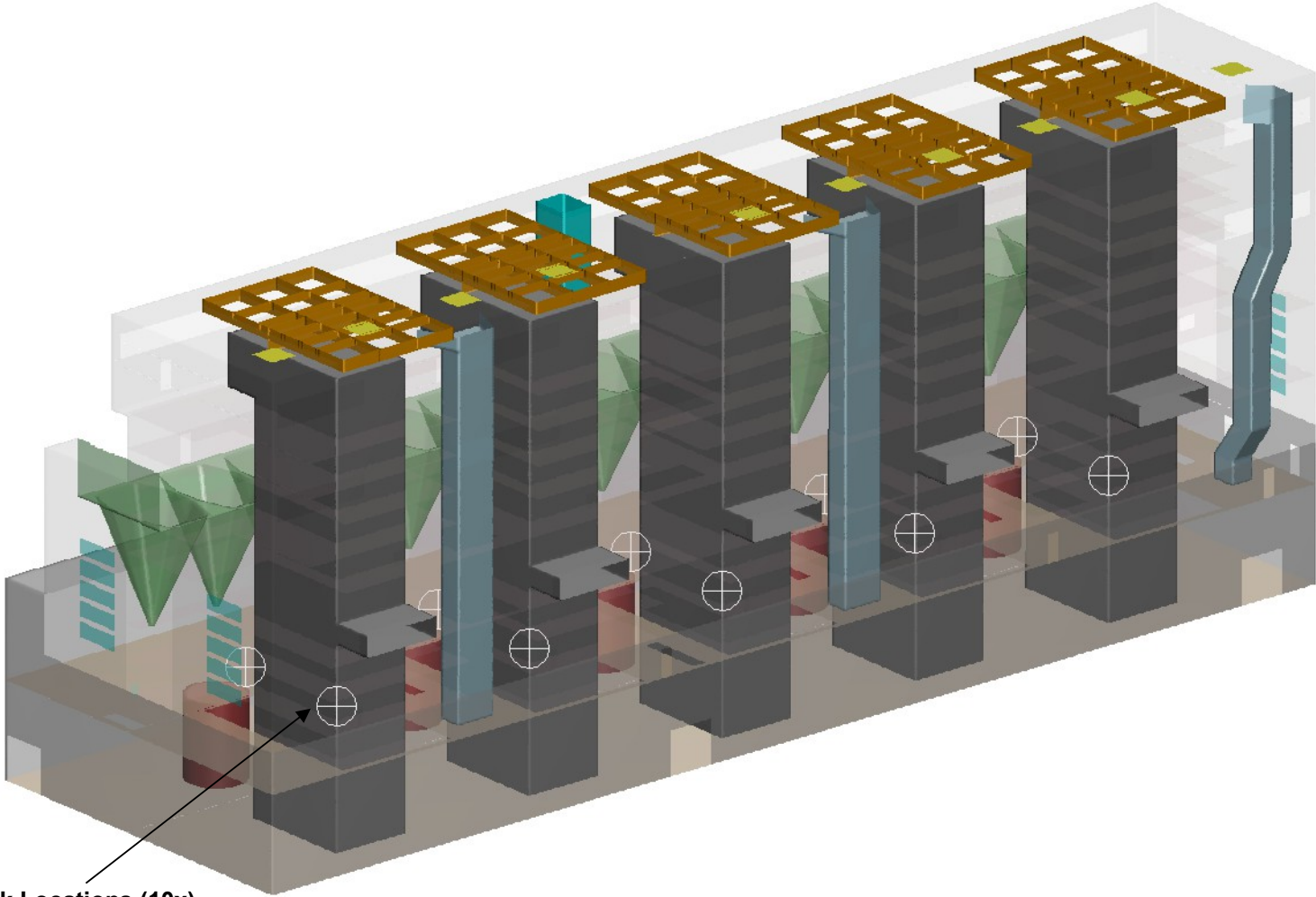
Time = 155 sec.



Airflow Sciences  
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# Case Study – Model Overview



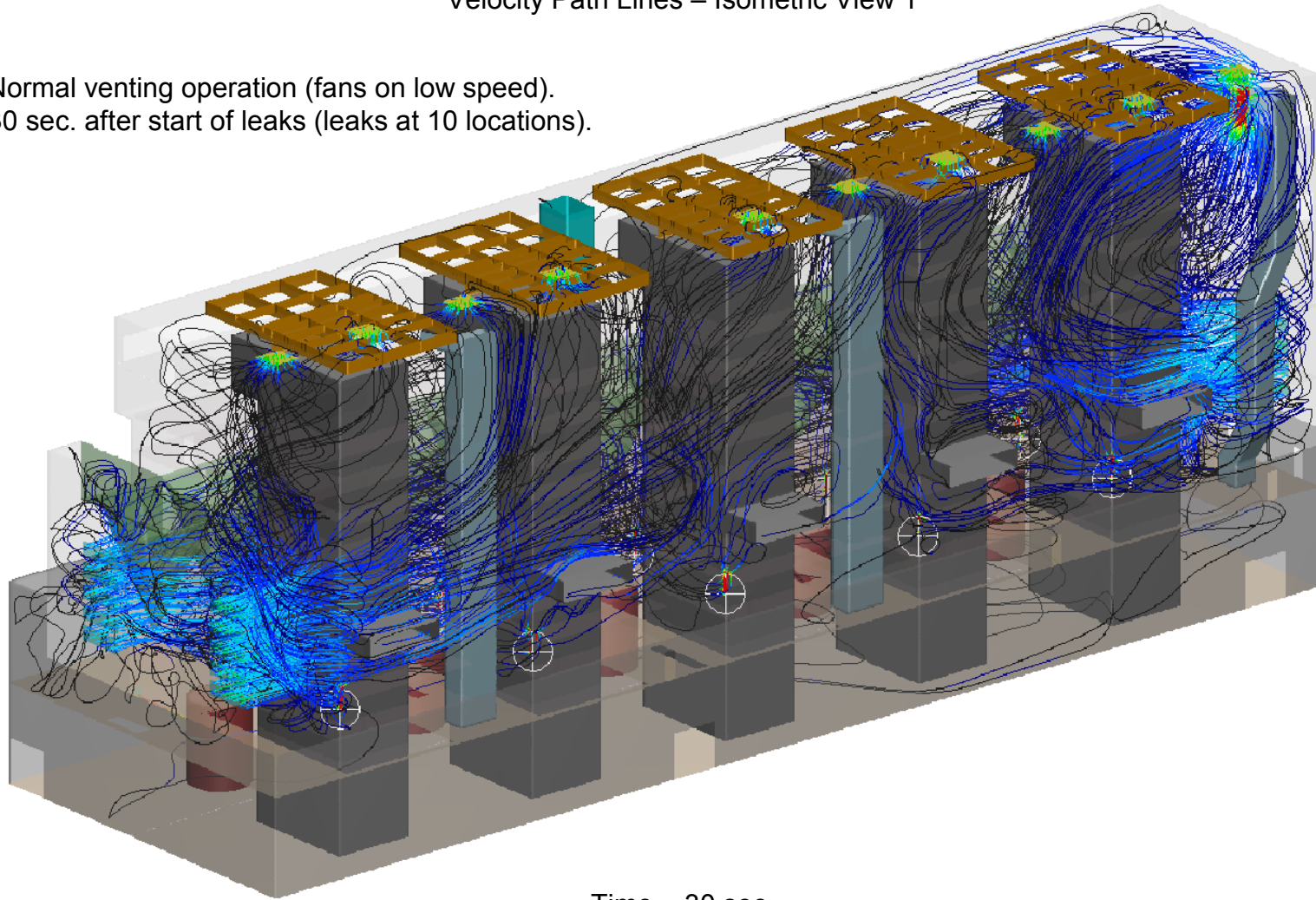
Leak Locations (10x)  
(Crosshairs)



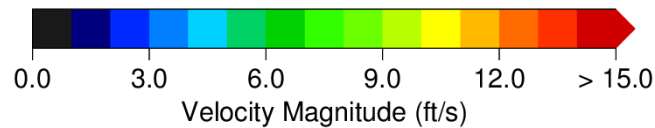
# Case Study – Venting Flow

Velocity Path Lines – Isometric View 1

- Normal venting operation (fans on low speed).
- 30 sec. after start of leaks (leaks at 10 locations).



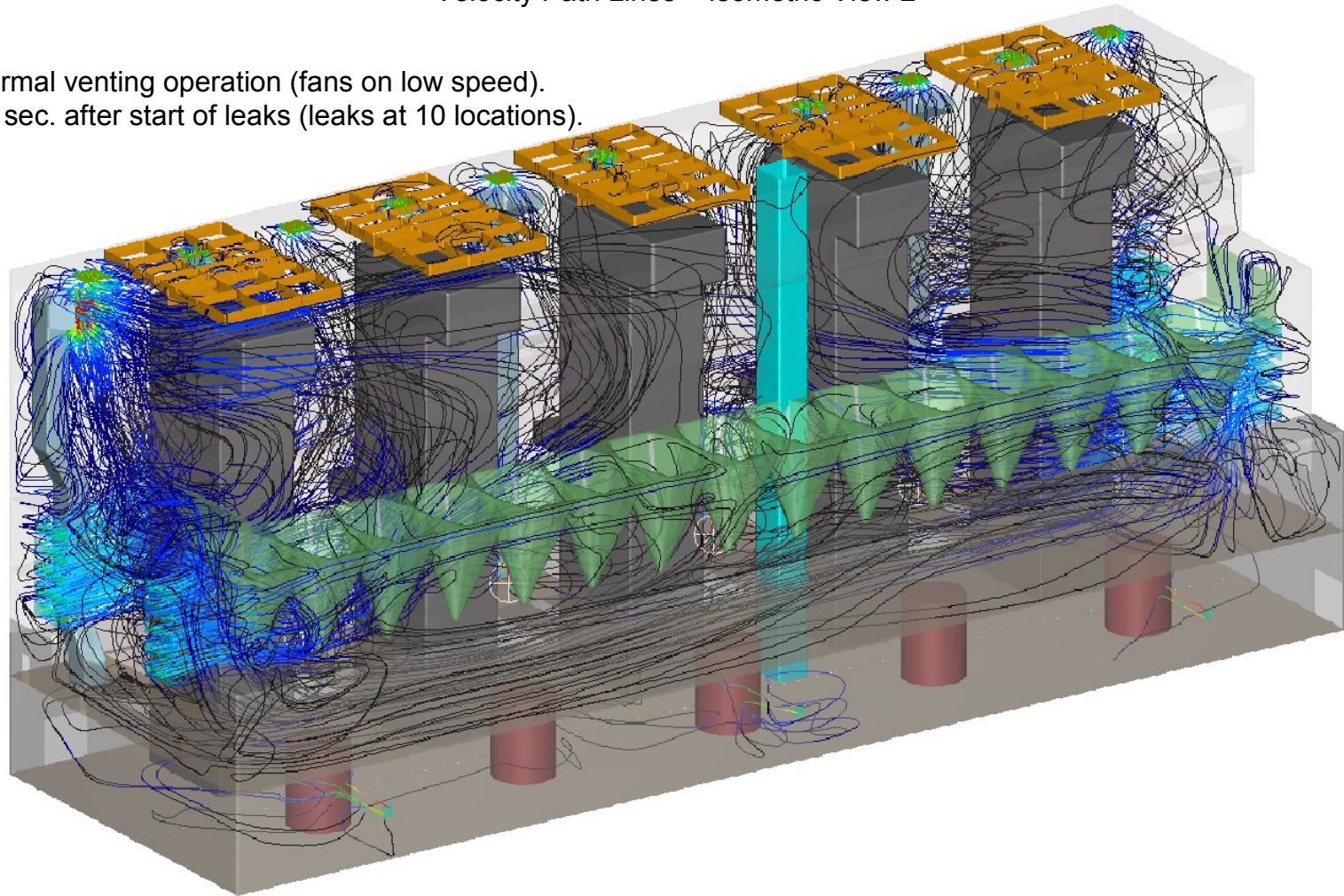
Time = 30 sec.



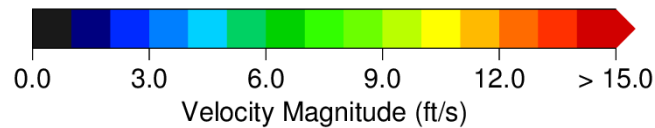
# Case Study – Venting Flow

Velocity Path Lines – Isometric View 2

- Normal venting operation (fans on low speed).
- 30 sec. after start of leaks (leaks at 10 locations).



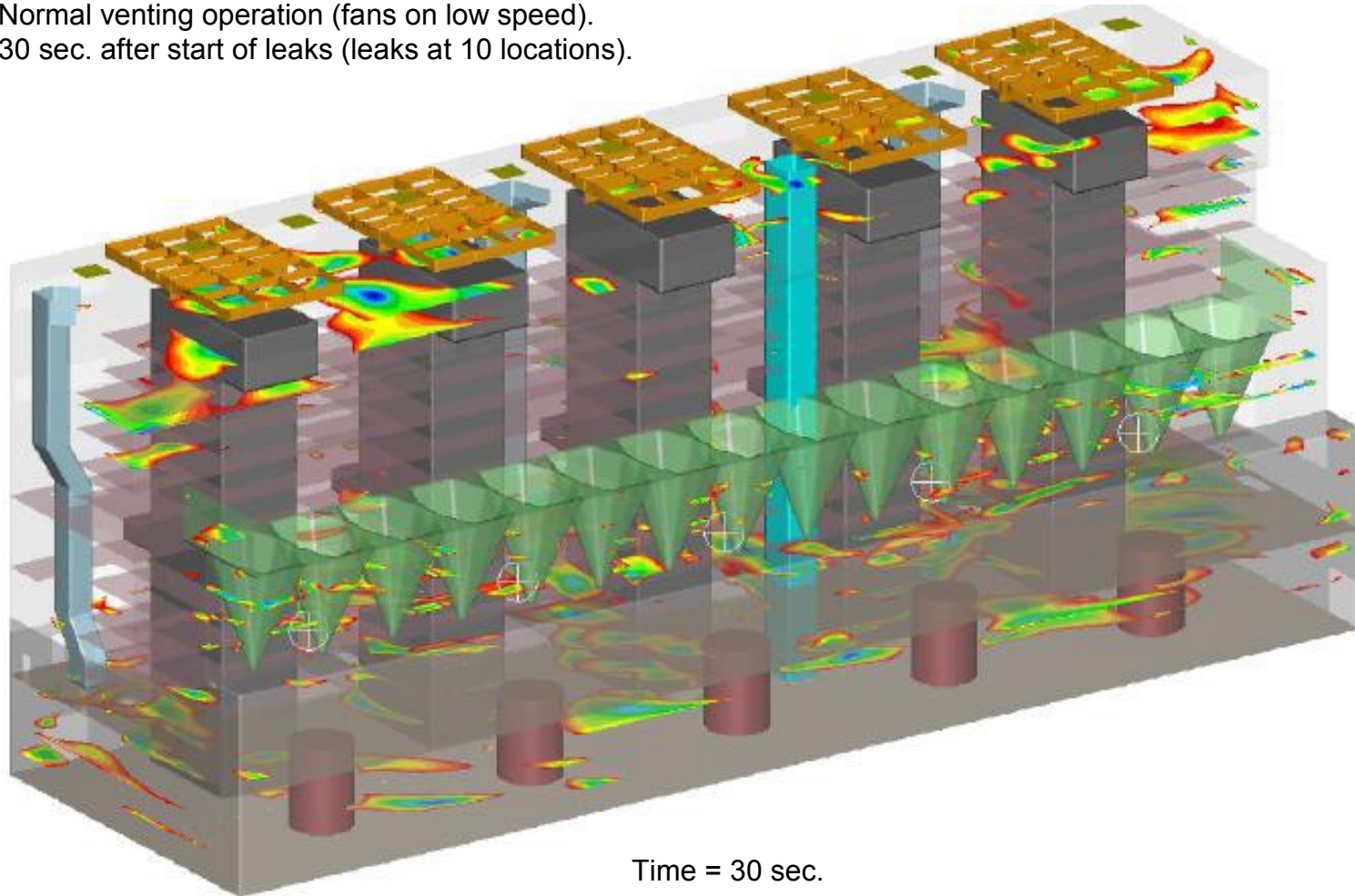
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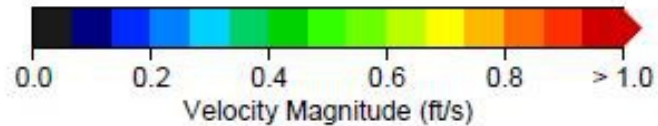
# Case Study – Venting Flow

Low velocity regions ( $< 1$  ft/s)

- Normal venting operation (fans on low speed).
- 30 sec. after start of leaks (leaks at 10 locations).



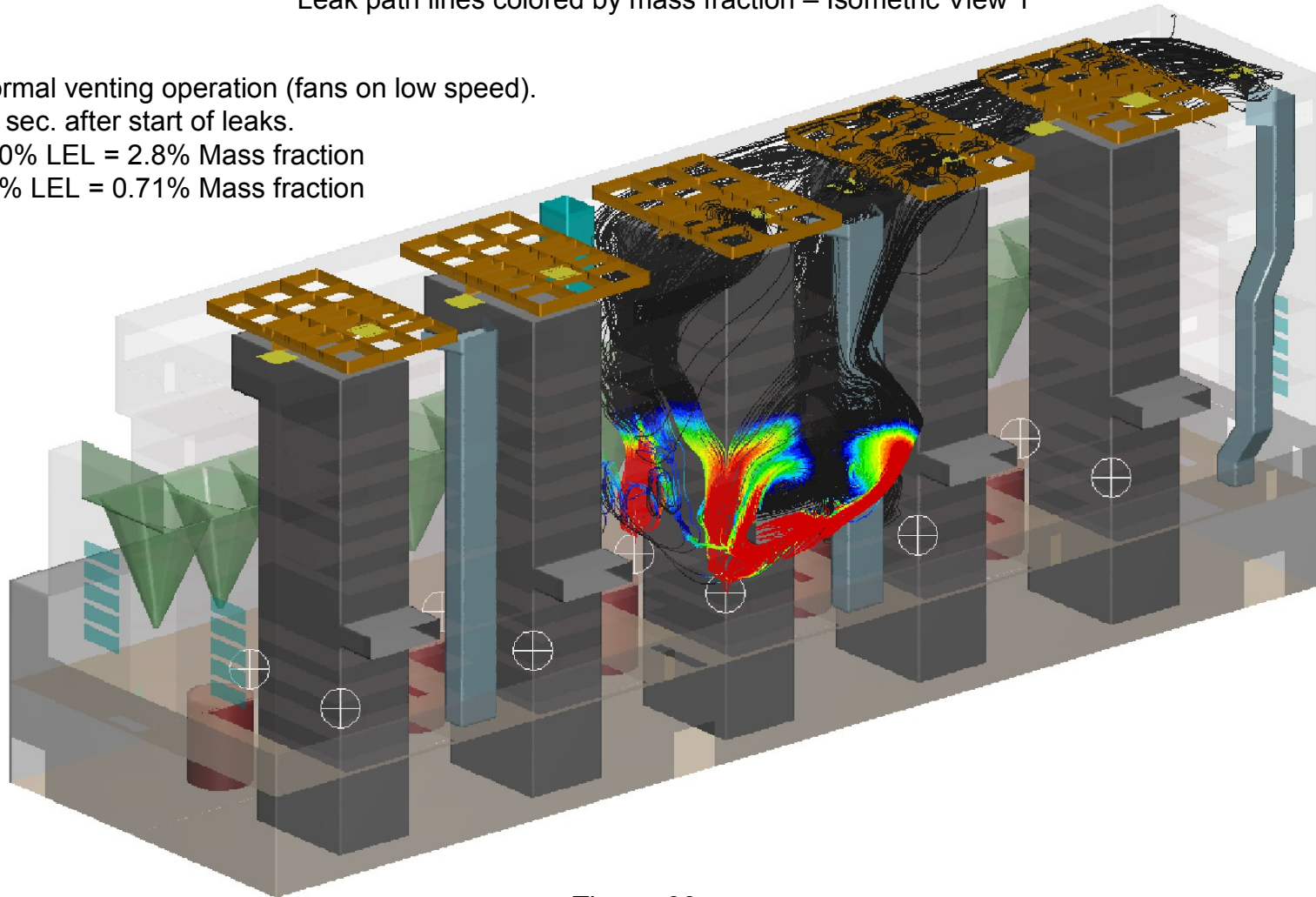
Time = 30 sec.



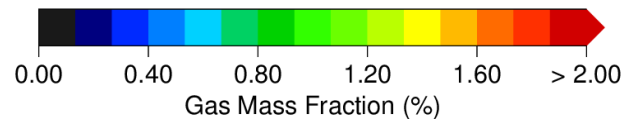
# Case Study – Leak Tracking

Leak path lines colored by mass fraction – Isometric View 1

- Normal venting operation (fans on low speed).
- 30 sec. after start of leaks.
- 100% LEL = 2.8% Mass fraction
- 25% LEL = 0.71% Mass fraction



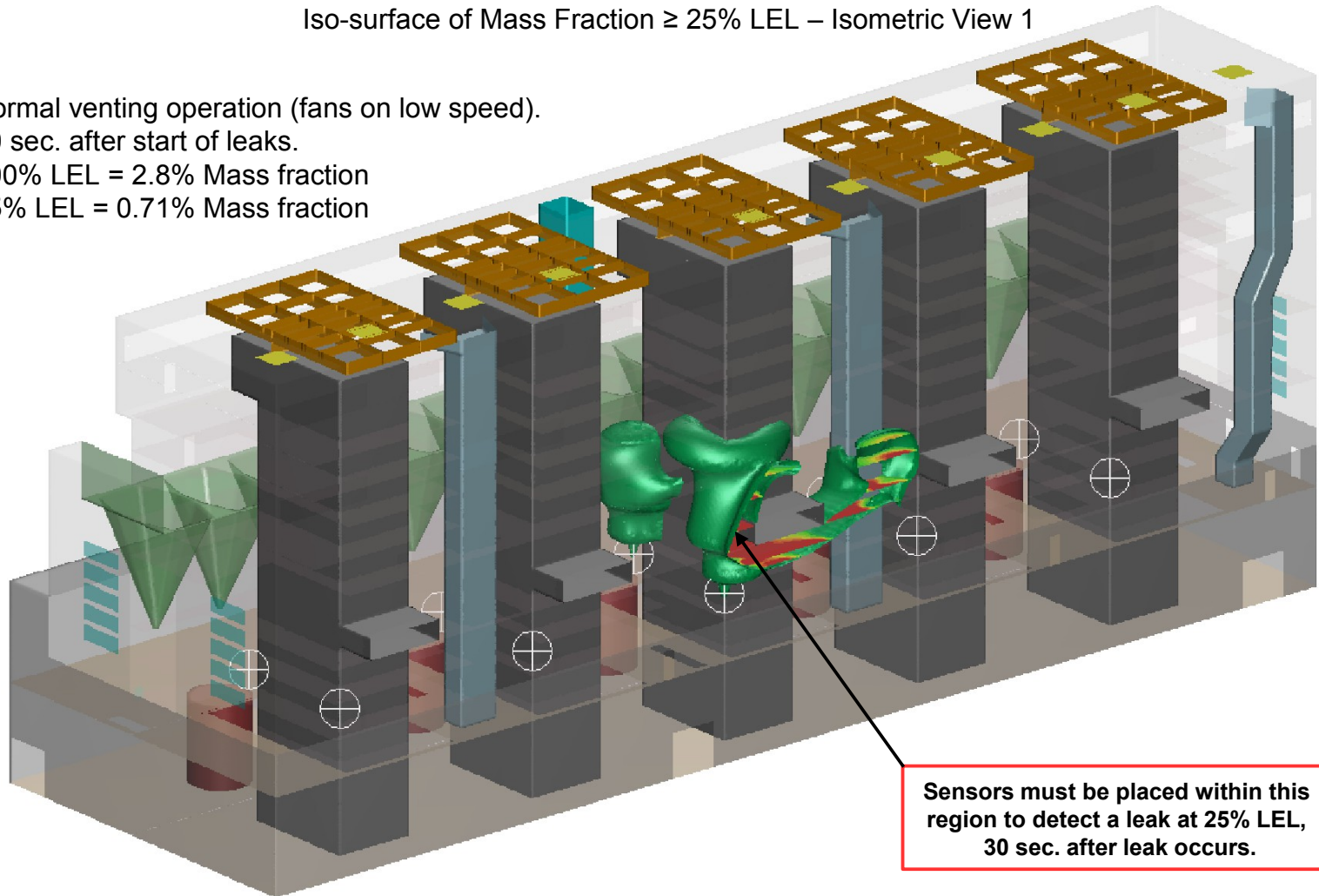
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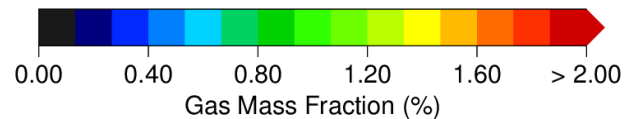
# Case Study – Leak Tracking

Iso-surface of Mass Fraction  $\geq 25\%$  LEL – Isometric View 1

- Normal venting operation (fans on low speed).
- 30 sec. after start of leaks.
- 100% LEL = 2.8% Mass fraction
- 25% LEL = 0.71% Mass fraction



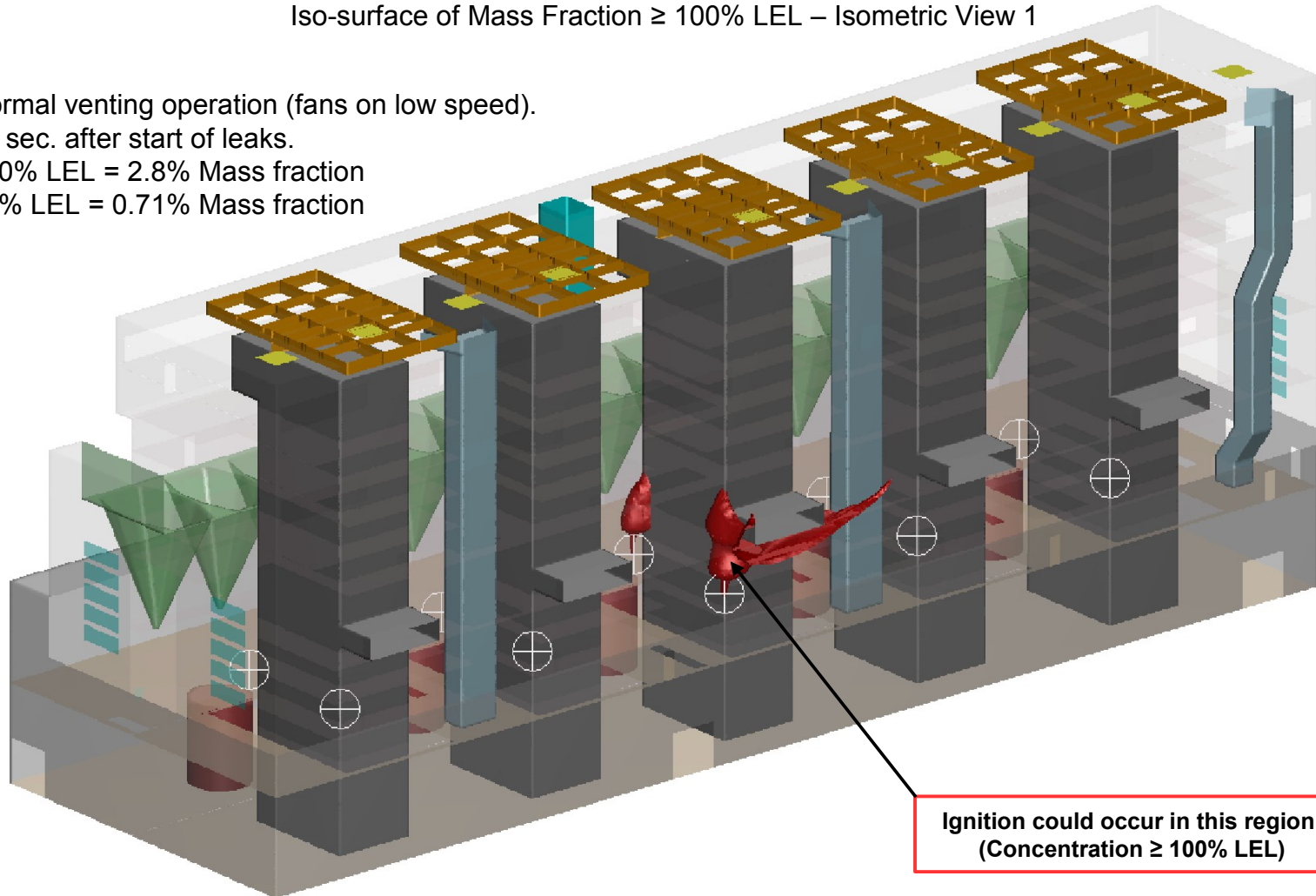
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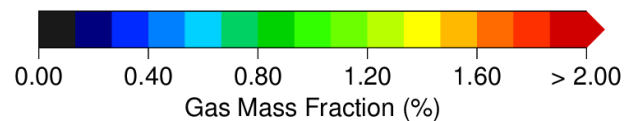
# Case Study – Leak Tracking

Iso-surface of Mass Fraction  $\geq 100\%$  LEL – Isometric View 1

- Normal venting operation (fans on low speed).
- 30 sec. after start of leaks.
- 100% LEL = 2.8% Mass fraction
- 25% LEL = 0.71% Mass fraction



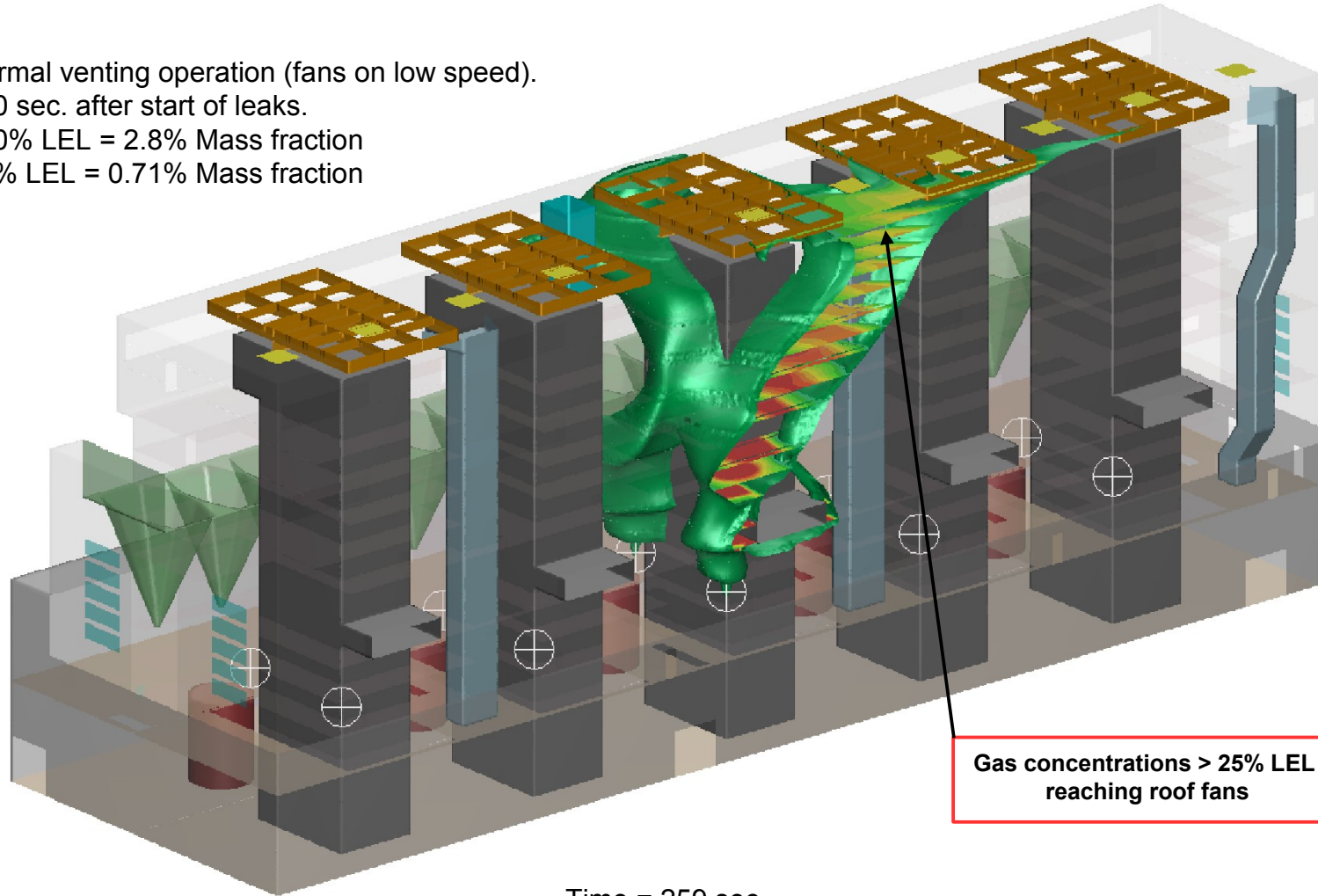
Time = 30 sec.



# Case Study – Leak Tracking

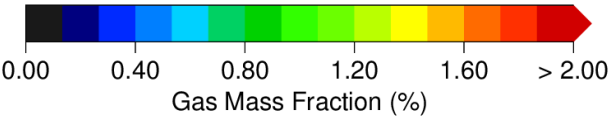
Iso-surface of Mass Fraction  $\geq 25\%$  LEL – Isometric View 1

- Normal venting operation (fans on low speed).
- 260 sec. after start of leaks.
- 100% LEL = 2.8% Mass fraction
- 25% LEL = 0.71% Mass fraction



Gas concentrations  $> 25\%$  LEL reaching roof fans

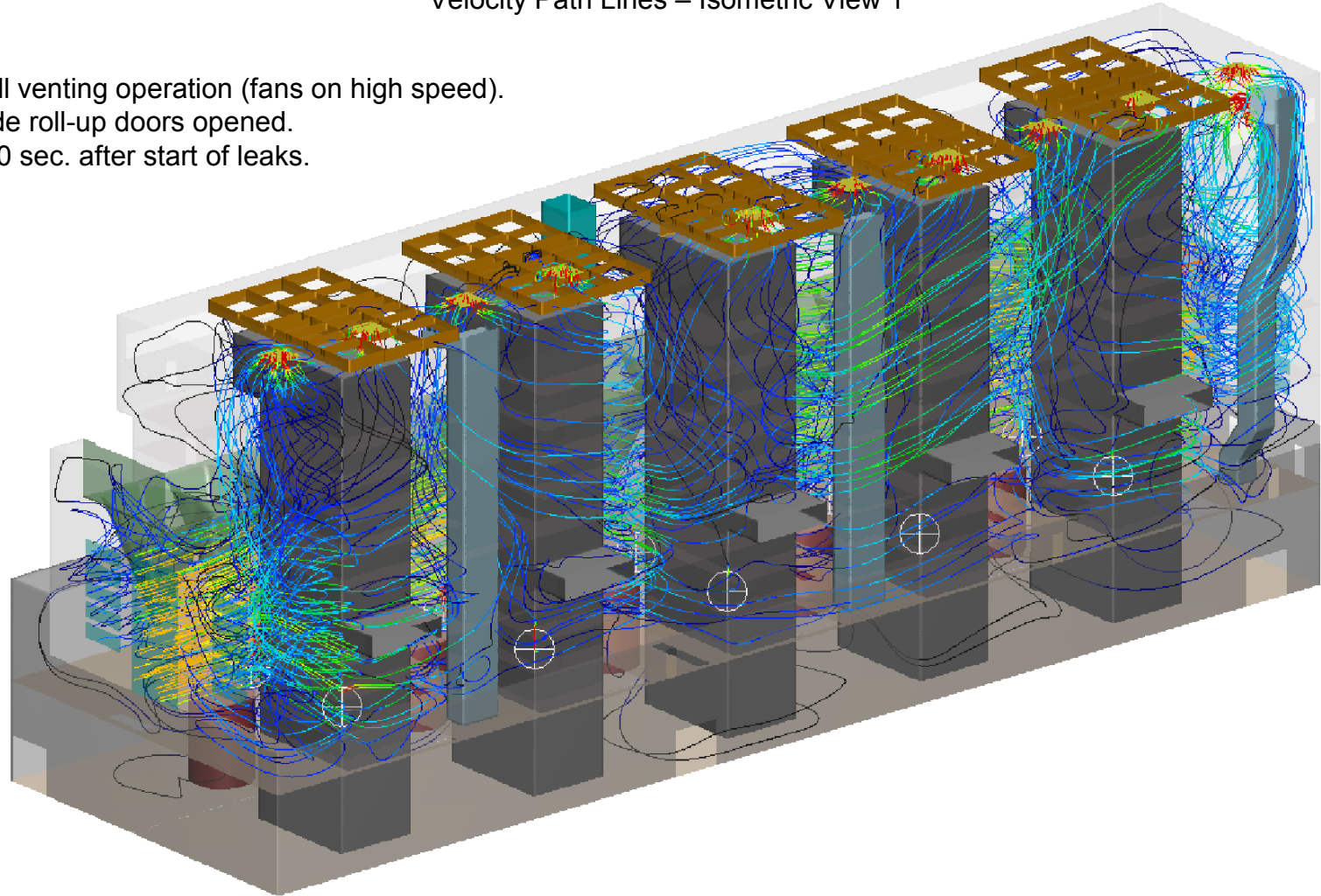
Time = 259 sec.



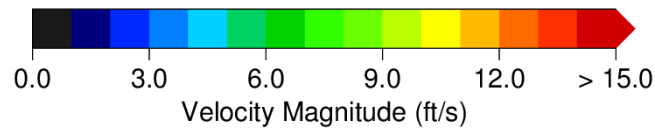
# Case Study – Venting Flow

Velocity Path Lines – Isometric View 1

- Full venting operation (fans on high speed).
- Side roll-up doors opened.
- 500 sec. after start of leaks.



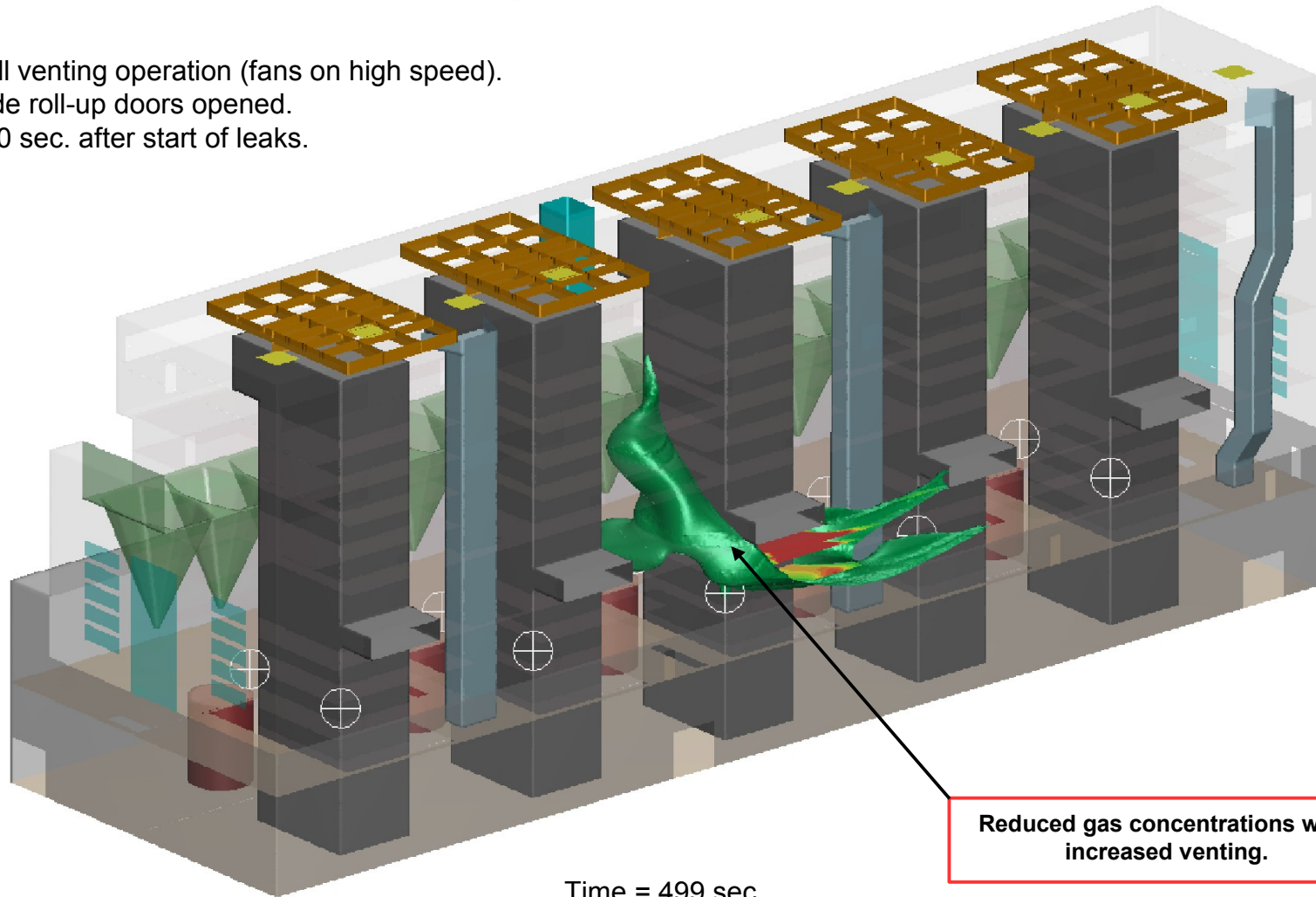
Time = 499 sec.



# Case Study – Leak Tracking

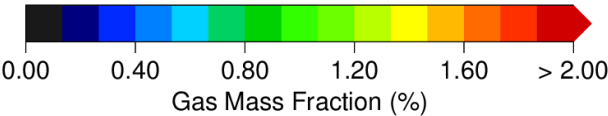
Iso-surface of Mass Fraction  $\geq 25\%$  LEL – Isometric View 1

- Full venting operation (fans on high speed).
- Side roll-up doors opened.
- 500 sec. after start of leaks.



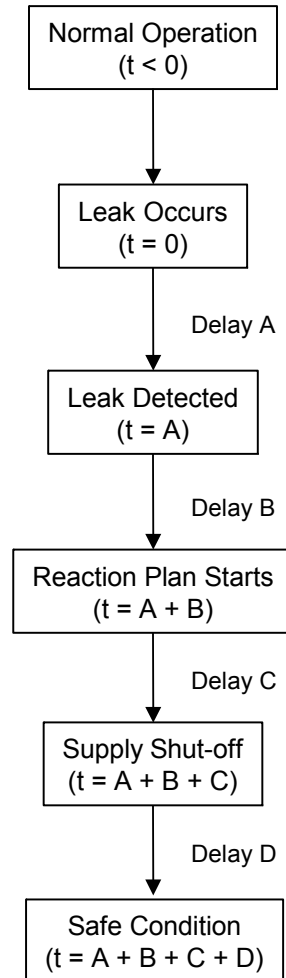
Reduced gas concentrations with increased venting.

Time = 499 sec.



# Case Study – Reaction Sequence

Typical Leak Reaction Plan (Timeline)



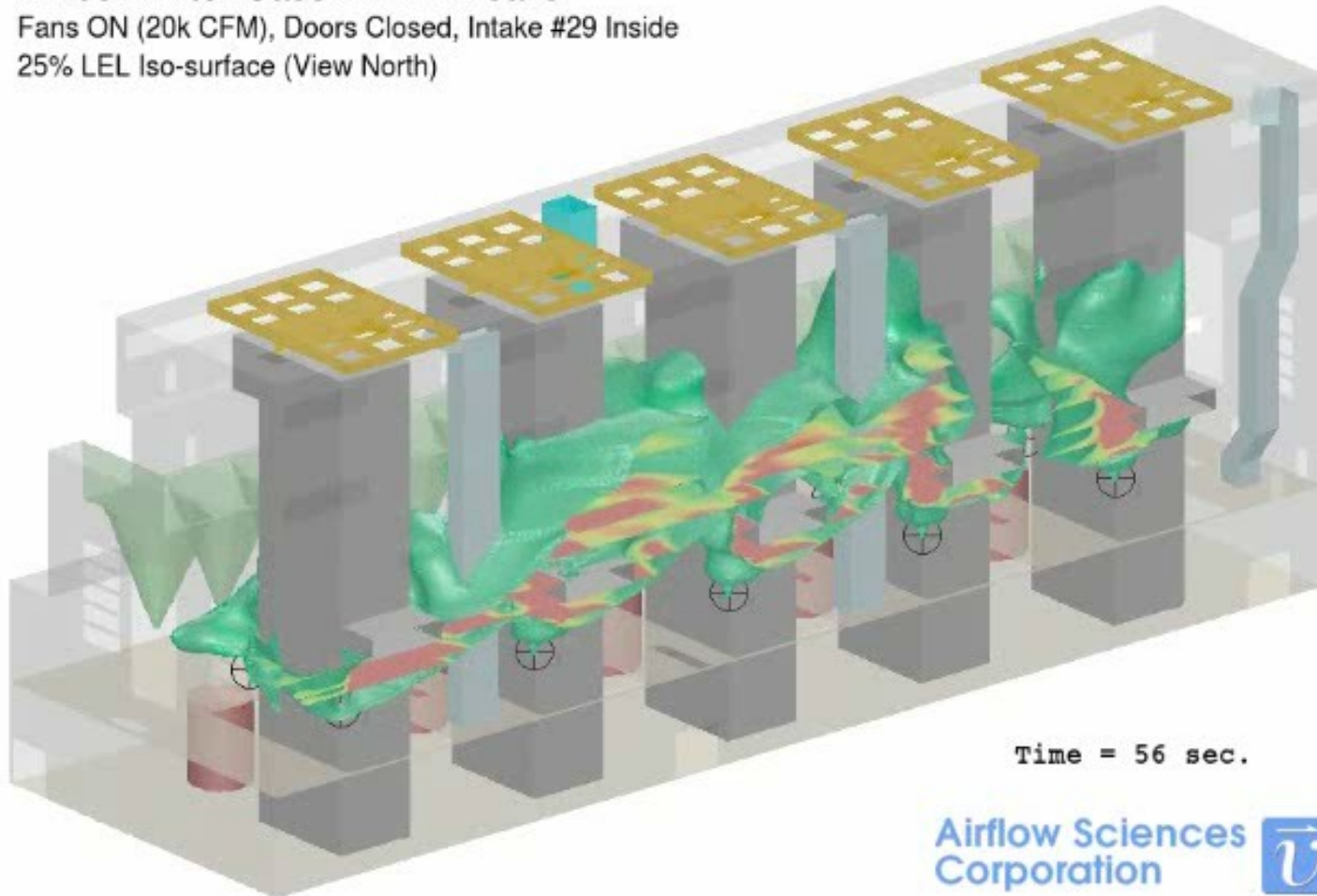
# Case Study – Reaction Sequence

Evolution of iso-surface (mass Fraction  $\geq 25\%$  LEL) over full reaction sequence.

10 Simultaneous Leaks

## B-253 Winter Case #1 - All Leaks

Fans ON (20k CFM), Doors Closed, Intake #29 Inside  
25% LEL Iso-surface (View North)



Time = 56 sec.

# Case Study – Reaction Sequence

Evolution of iso-surface (mass Fraction  $\geq 25\%$  LEL) over full reaction sequence.

2 Leaks at Center Boiler

B-253 Winter Case #1 - Boiler #27 Leaks

Fans ON (20k CFM), Doors Closed, Intake #29 Inside

25% LEL Iso-surface (View North)



Time = 56 sec.

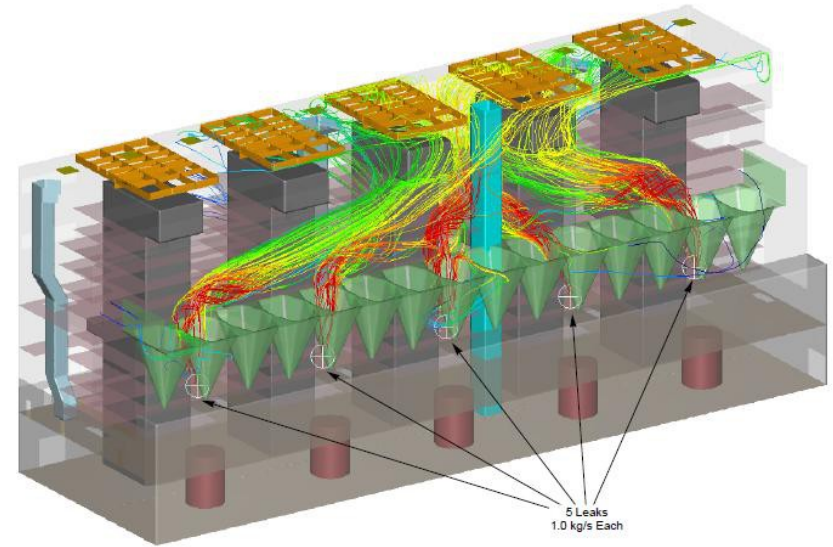
# Conclusions

- **Design parameters can be developed to minimize safety hazards**

- Allowable concentrations
- Response times

- **Equipment should be chosen to provide flexibility**

- Fans, VFDs
- New inlets, heating
- Detection instrumentation
- Dampers / actuators
- Reaction plan, control system



- **CFD modeling can be used to design the system**

- Perform “what if” studies of leak locations, reaction event sequence and timing
- Examine air velocity patterns at various fan settings and venting options
- Quantify natural gas concentrations versus time for numerous designs
- Determine final design geometry and operating parameters

# Questions?

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