Gas Accumulation Potential & Leak Detection when Converting to Gas

Coal to Gas / PCUG Conference
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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

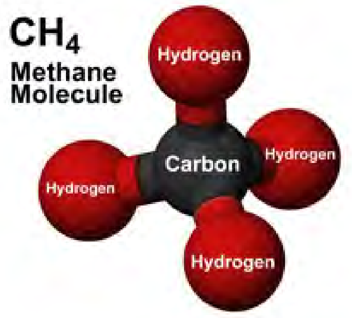
I. **Natural Gas Properties -> Ventilation Criteria**
   A) Buoyancy vs. air.
   B) Lower explosive limit (LEL).

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 (CH_4, C_2H_6).
  - Simulate as 100% Methane (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!

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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?

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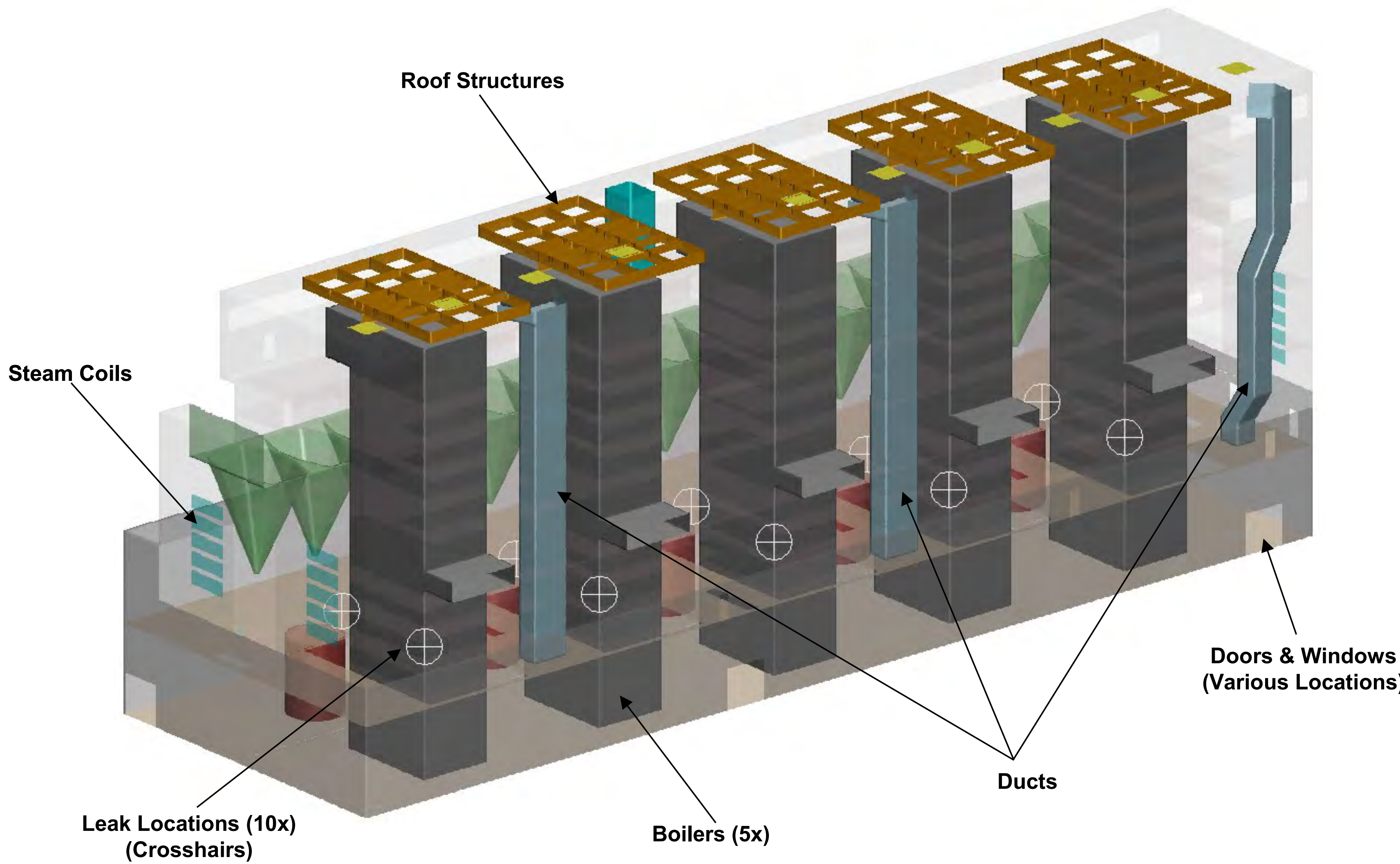
Case Study – Geometry Overview



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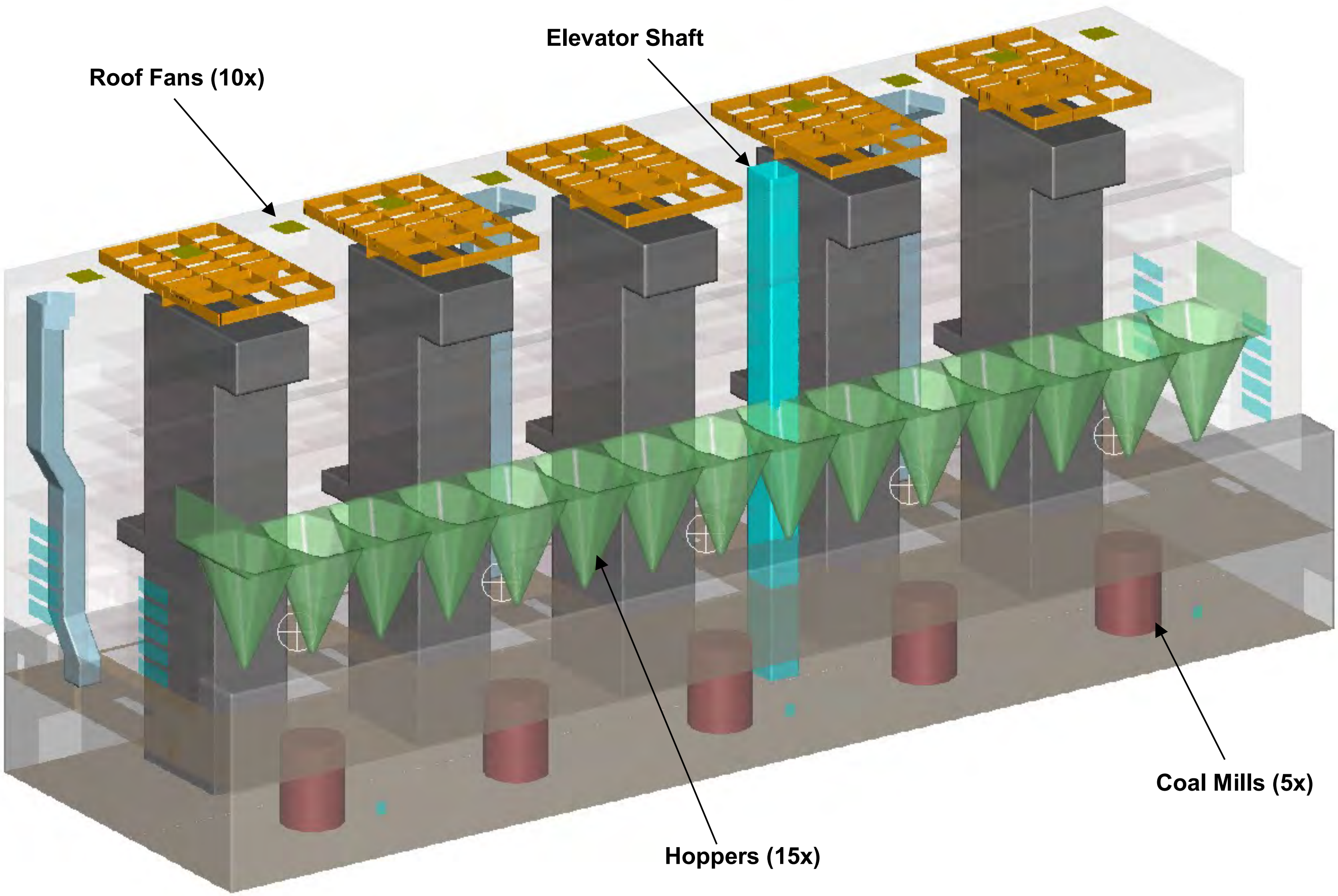
Case Study – Geometry Overview



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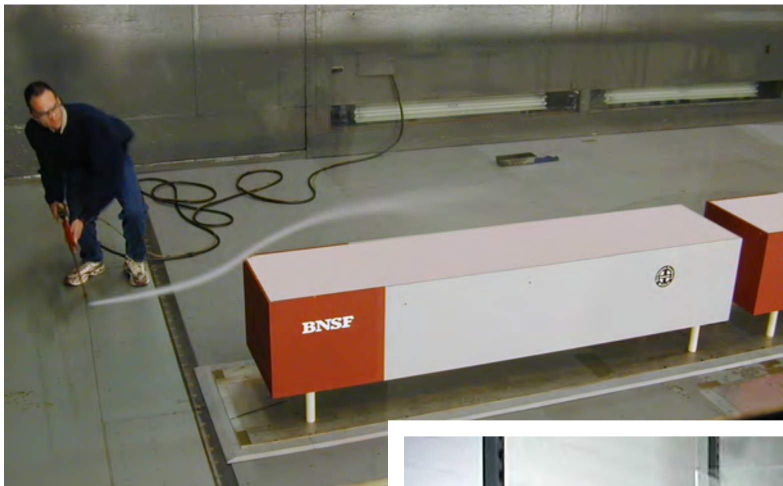
Flow Modeling Basics

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



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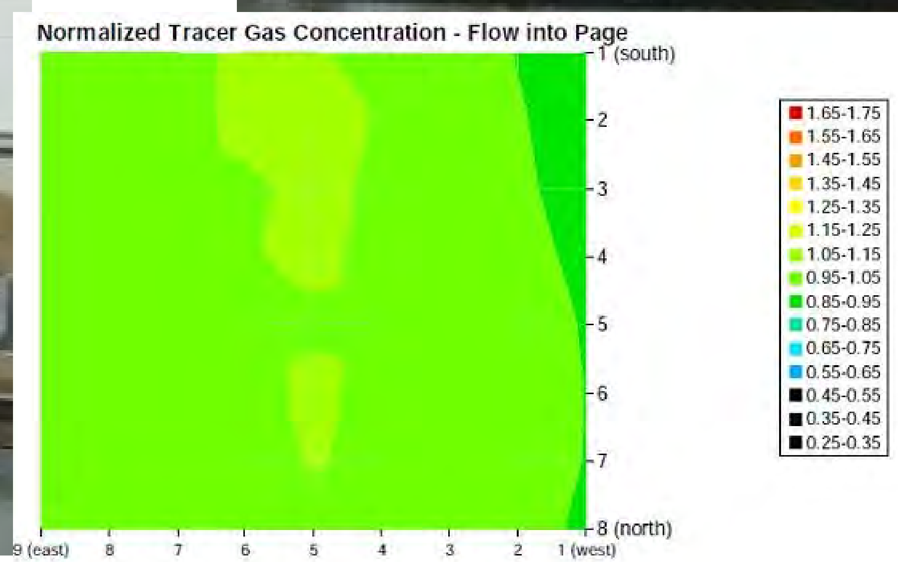
Physical Modeling Species Tracking

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



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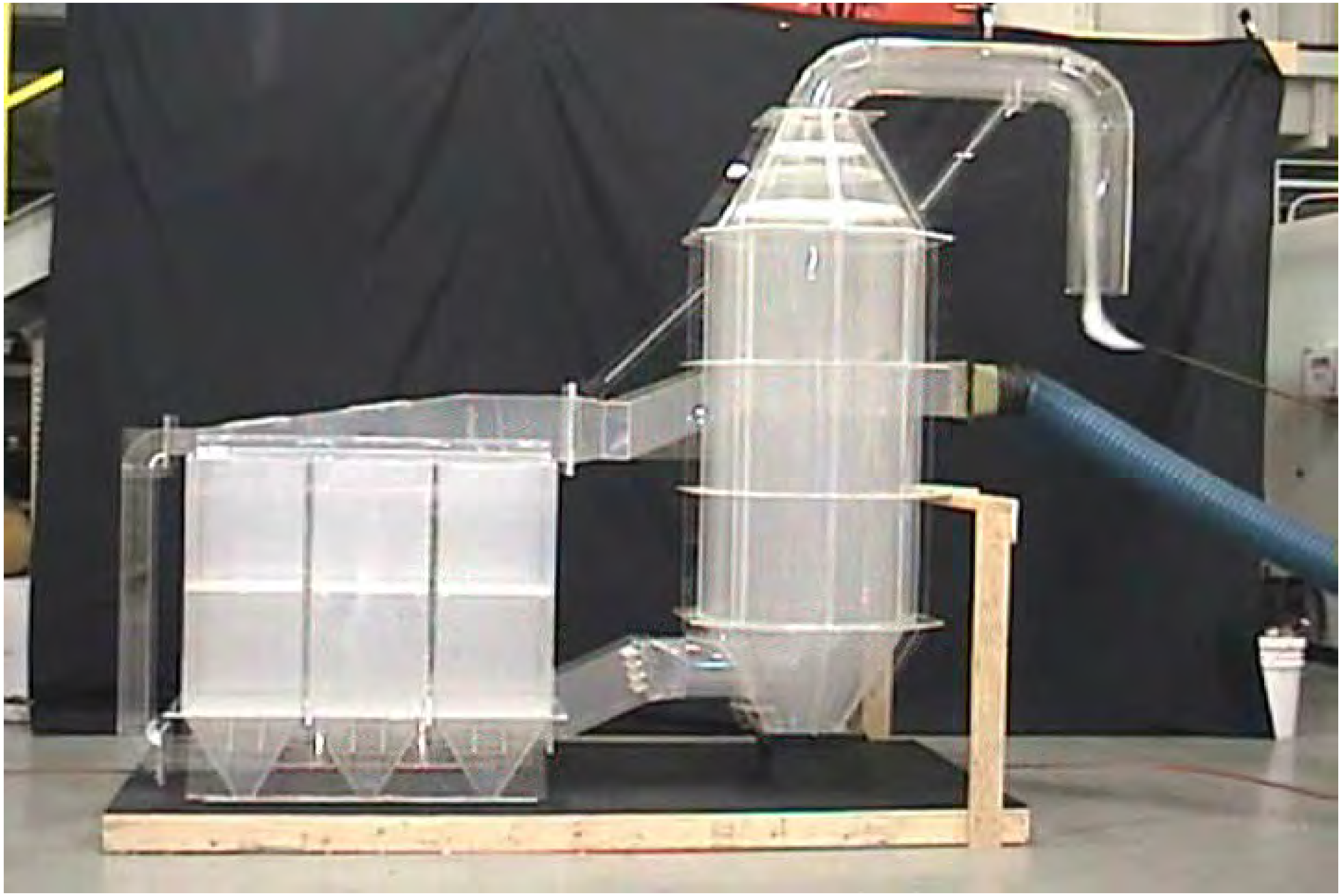
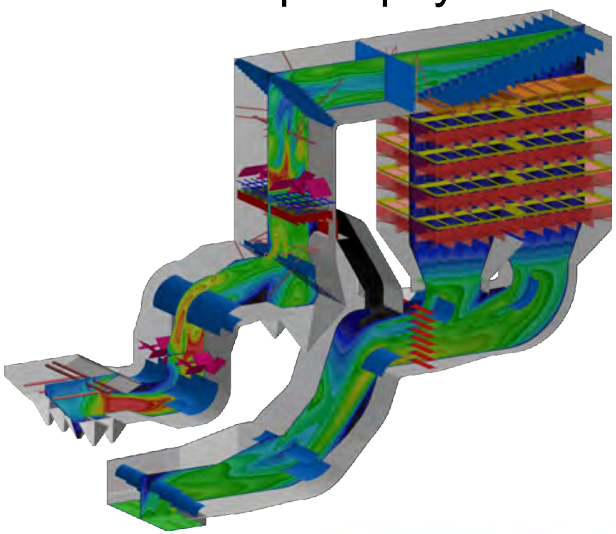
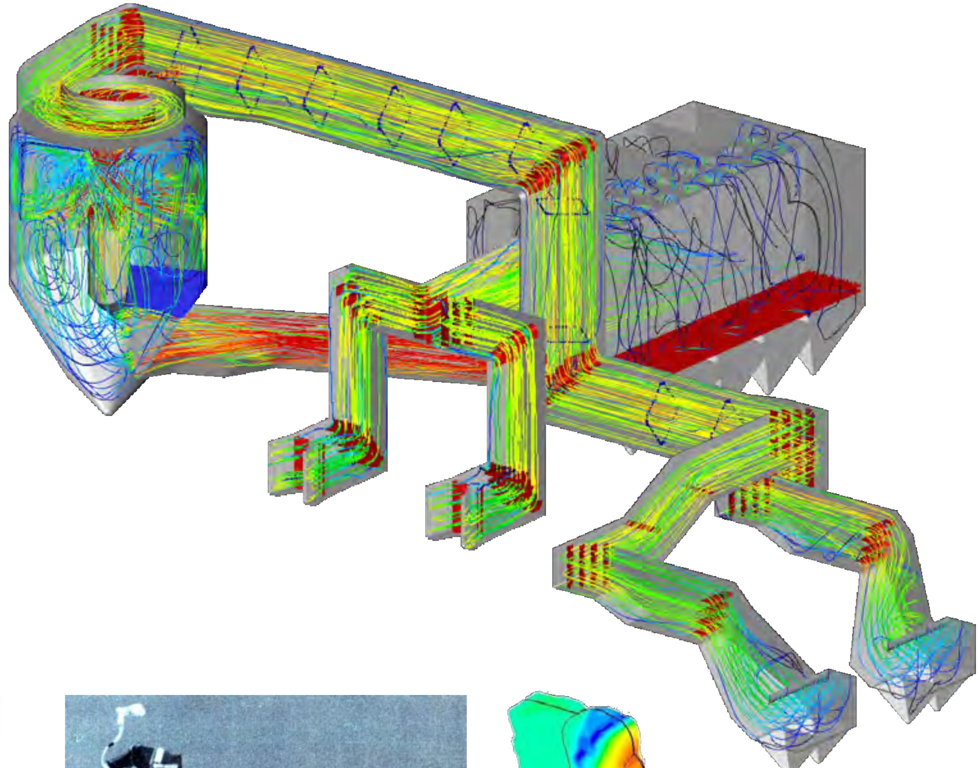
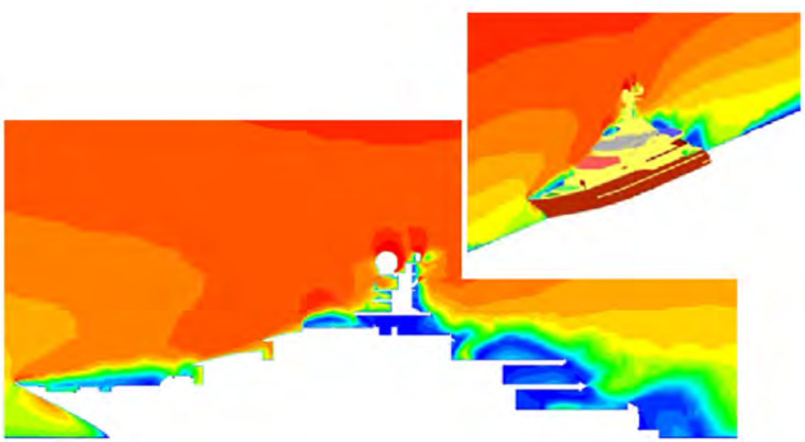


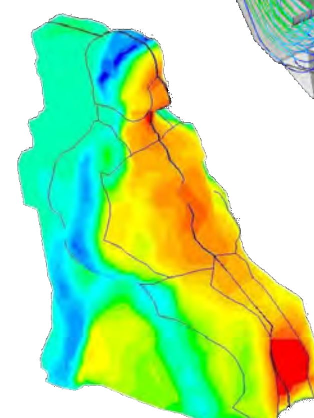
Flow Modeling Basics

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









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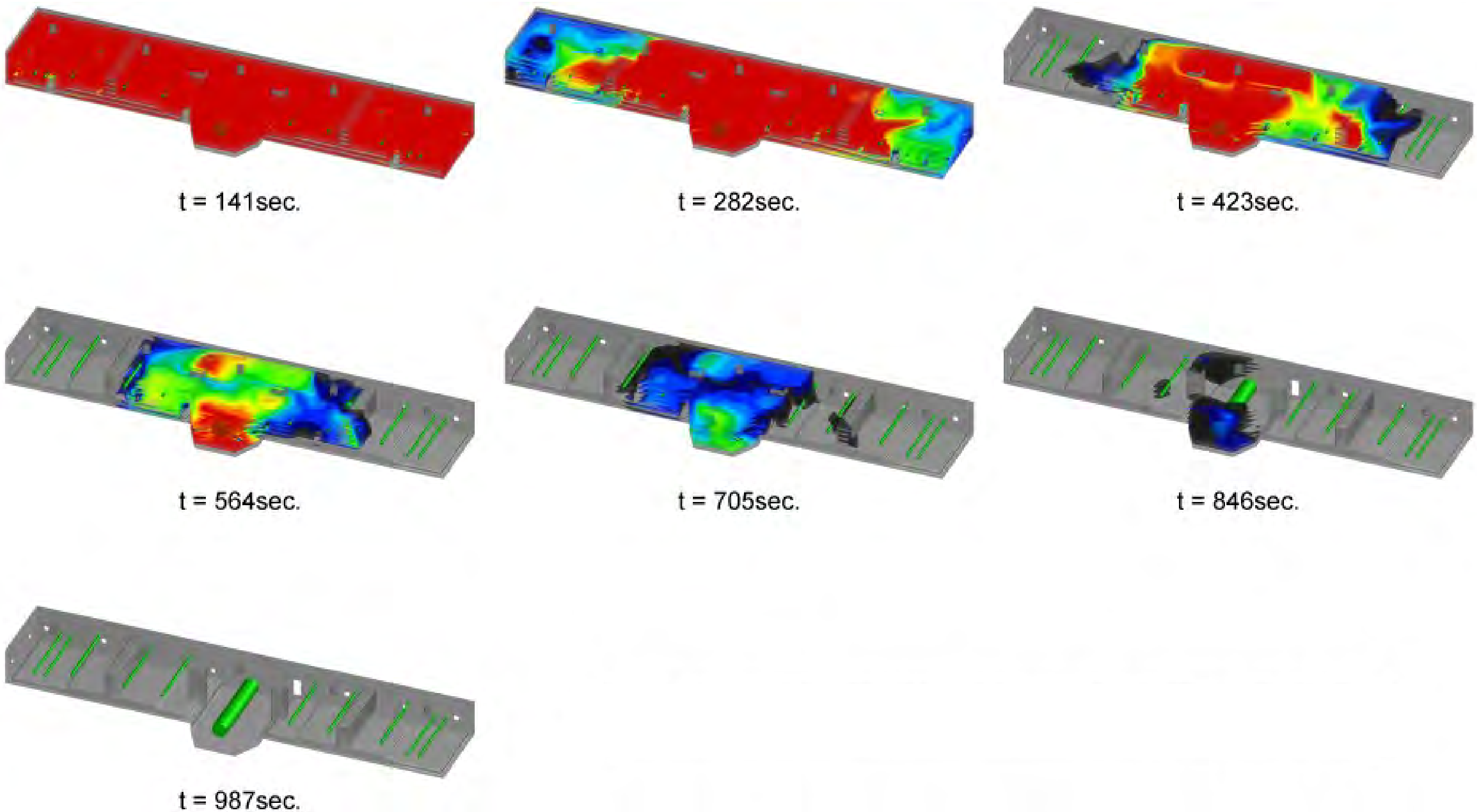
CFD Modeling Species Tracking

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



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CFD Modeling Species Tracking

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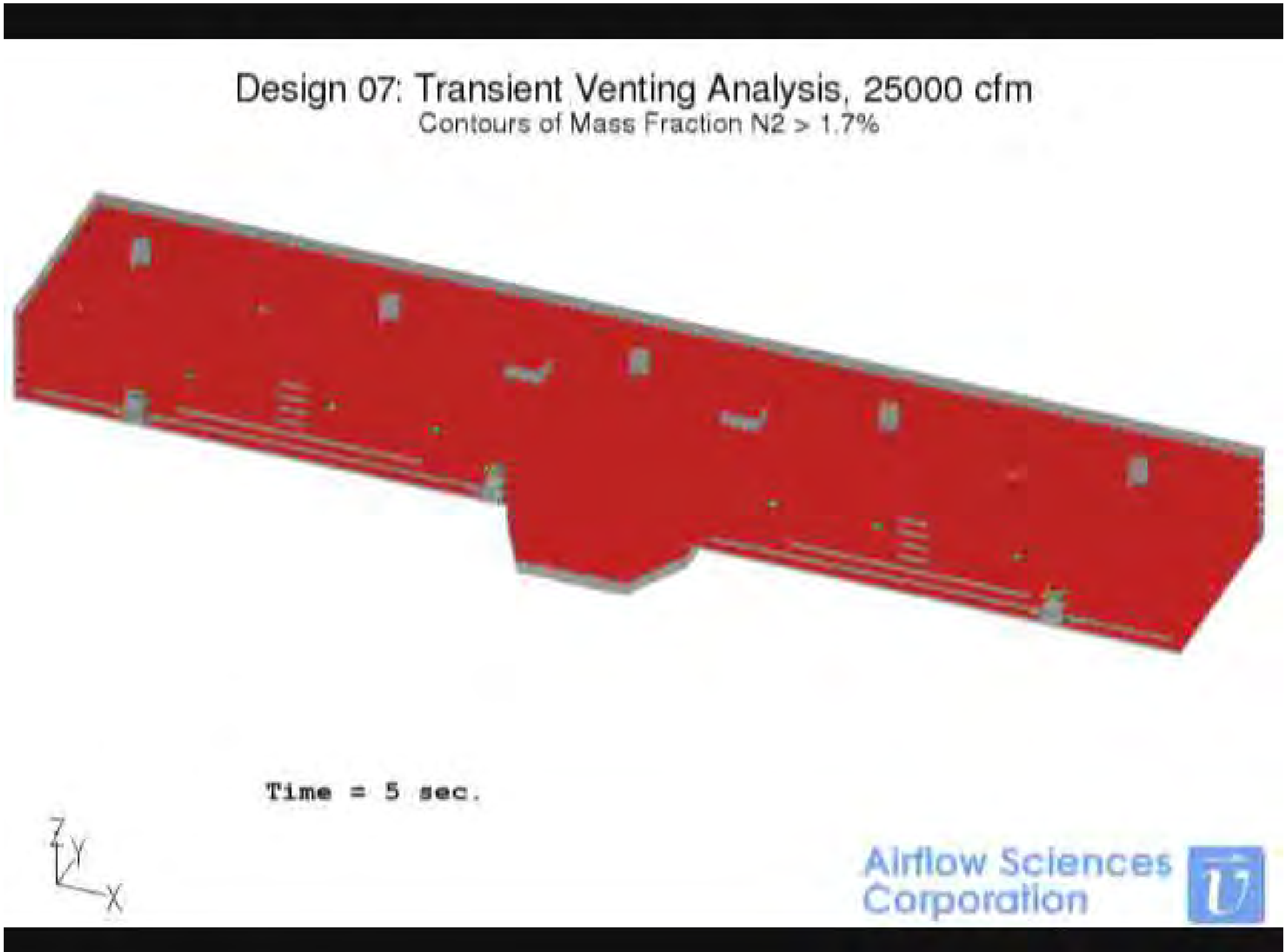
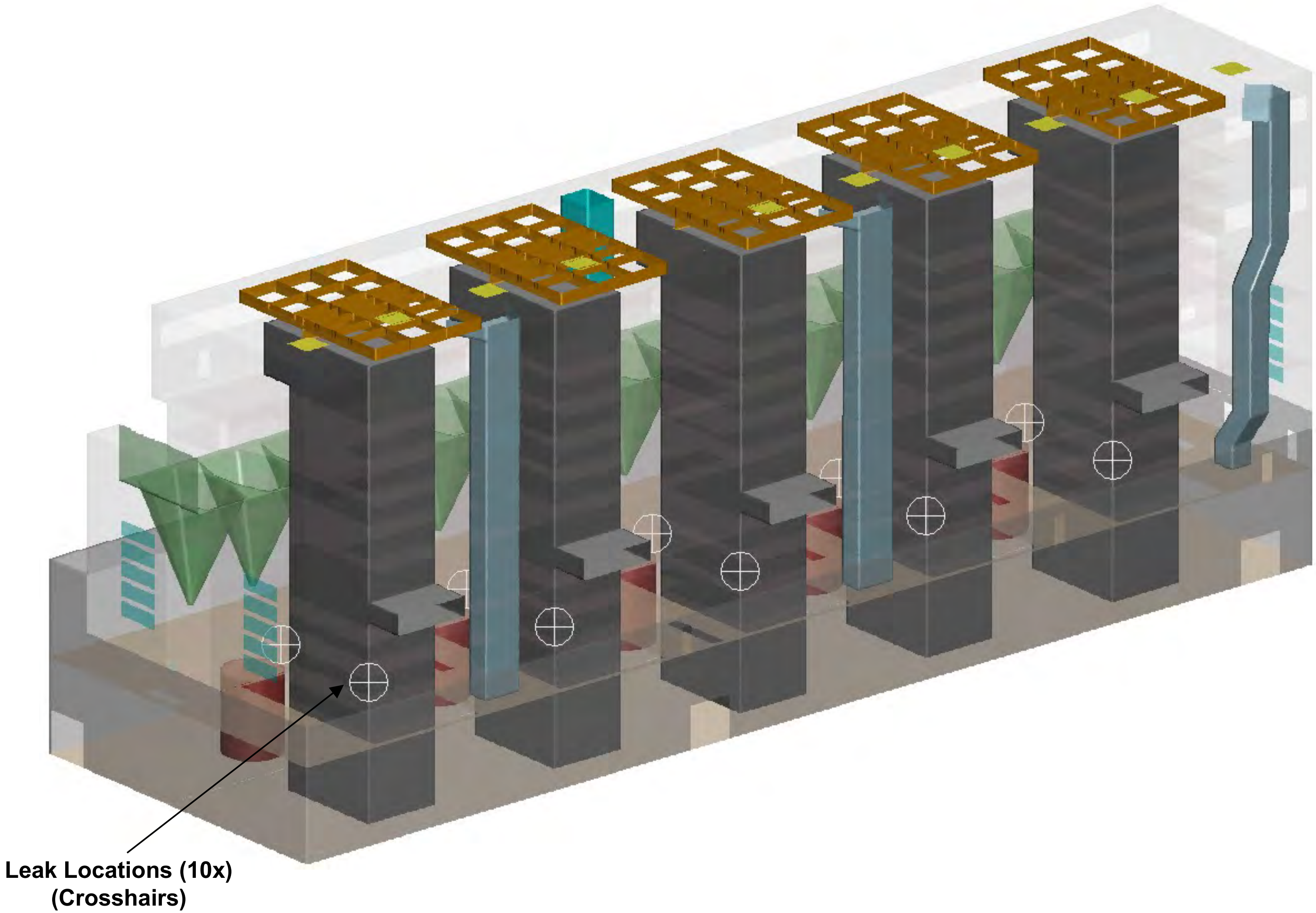


Case Study – Model Overview



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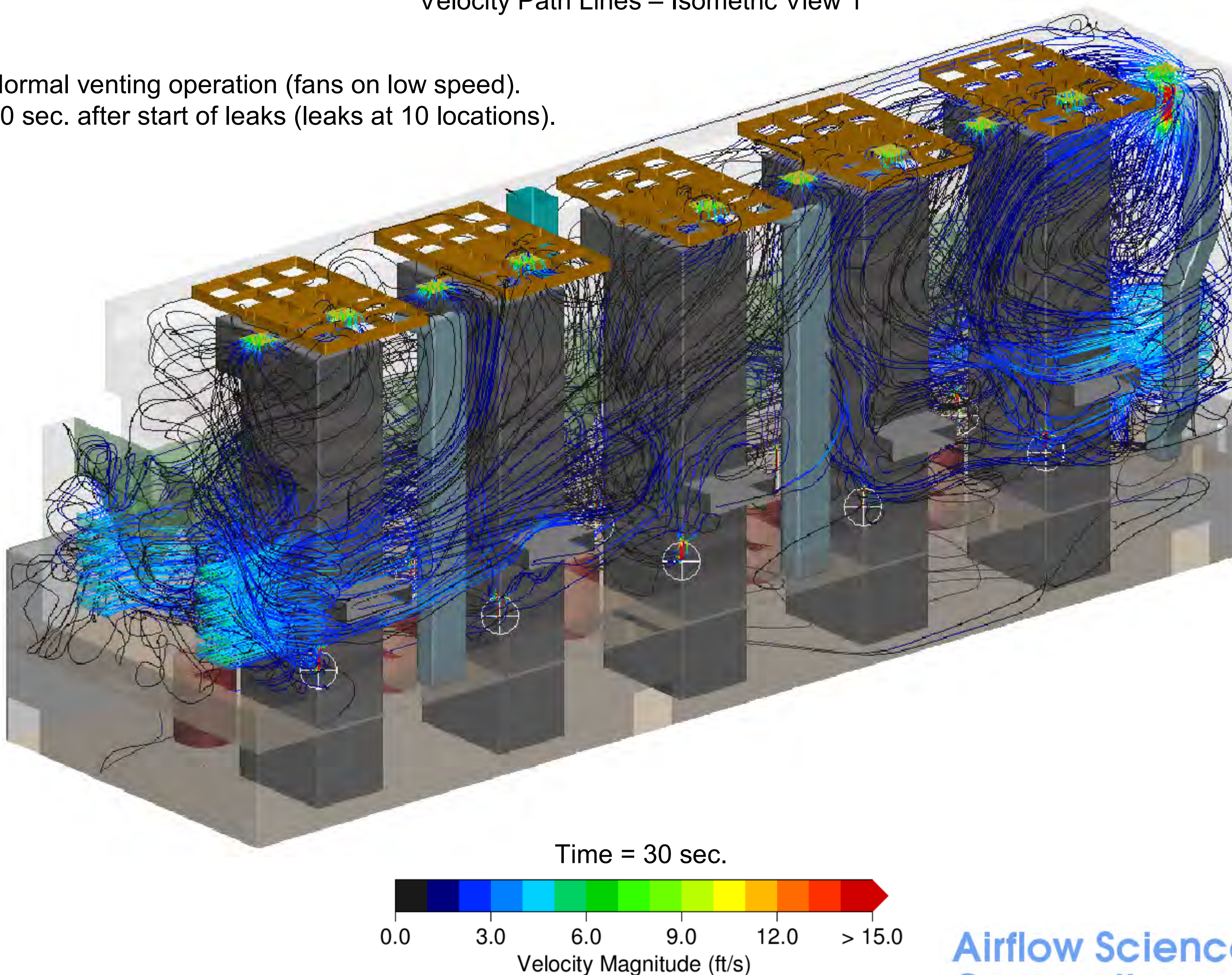
Case Study – Venting Flow

Velocity Path Lines – Isometric View 1

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



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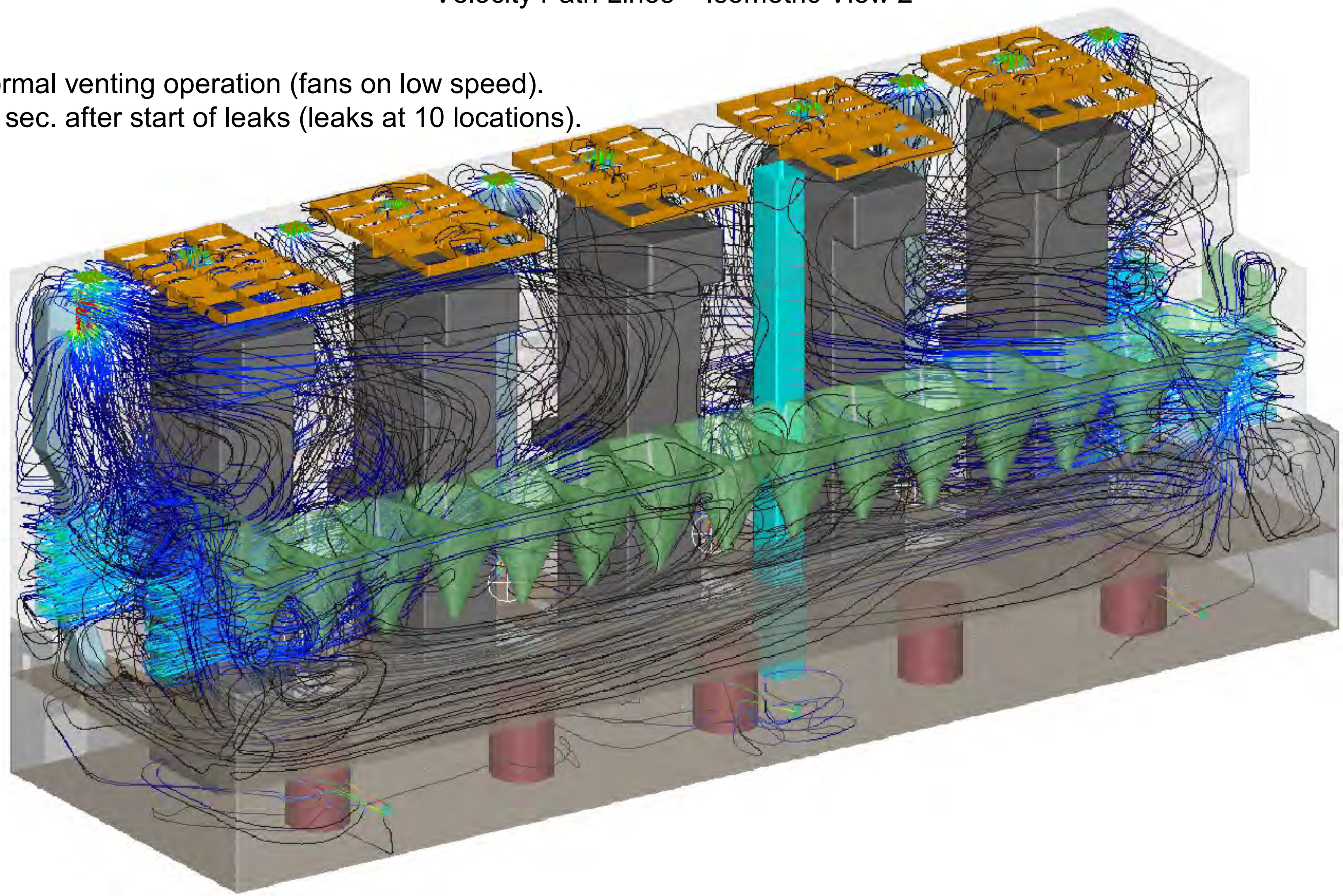
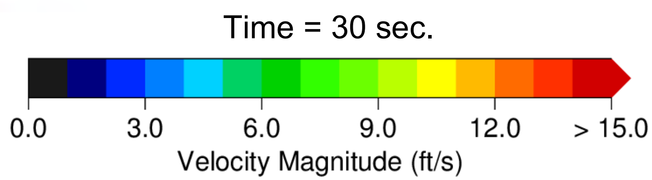
Case Study – Venting Flow

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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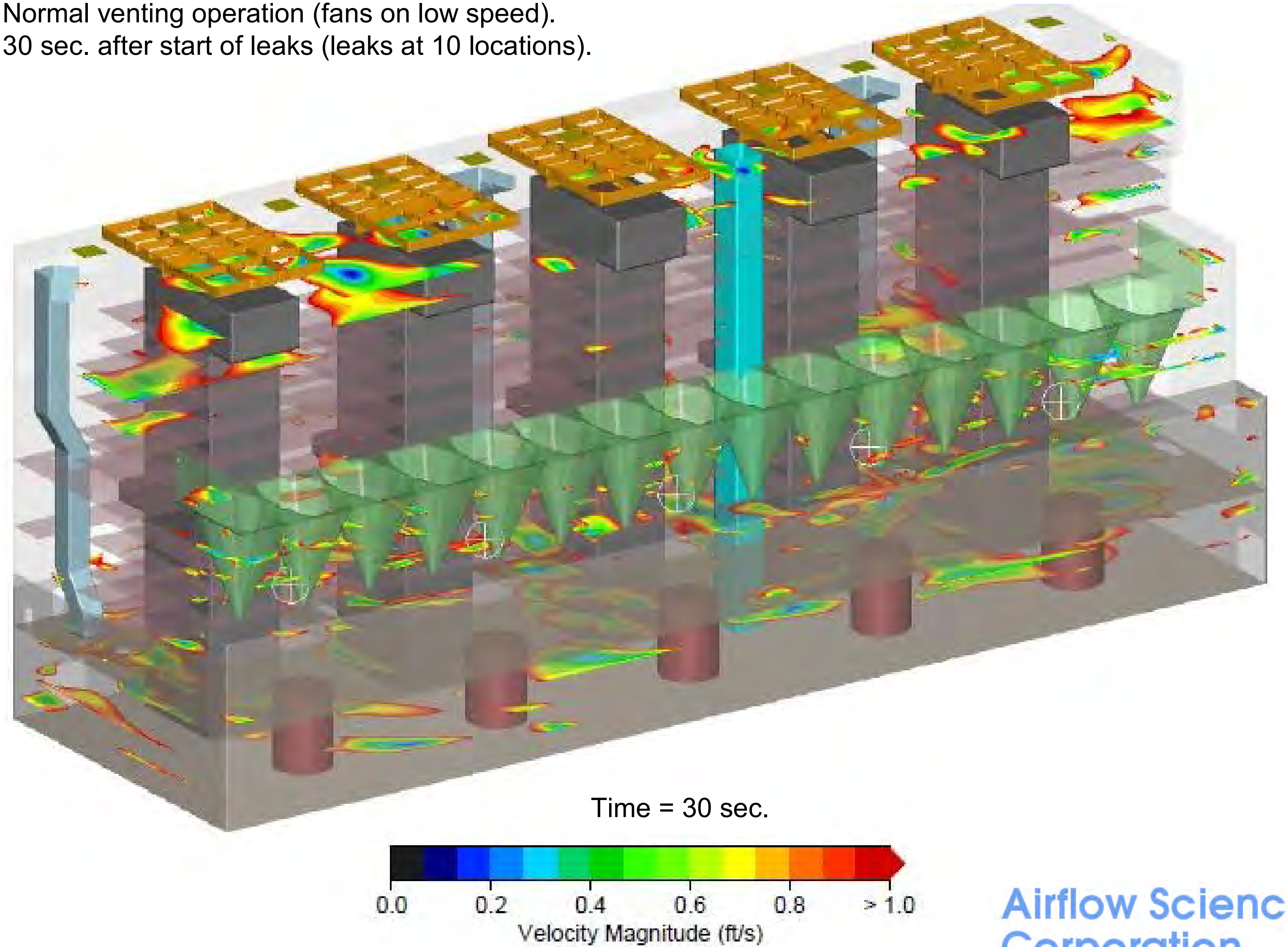
Case Study – Venting Flow

Low velocity regions (< 1 ft/s)

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



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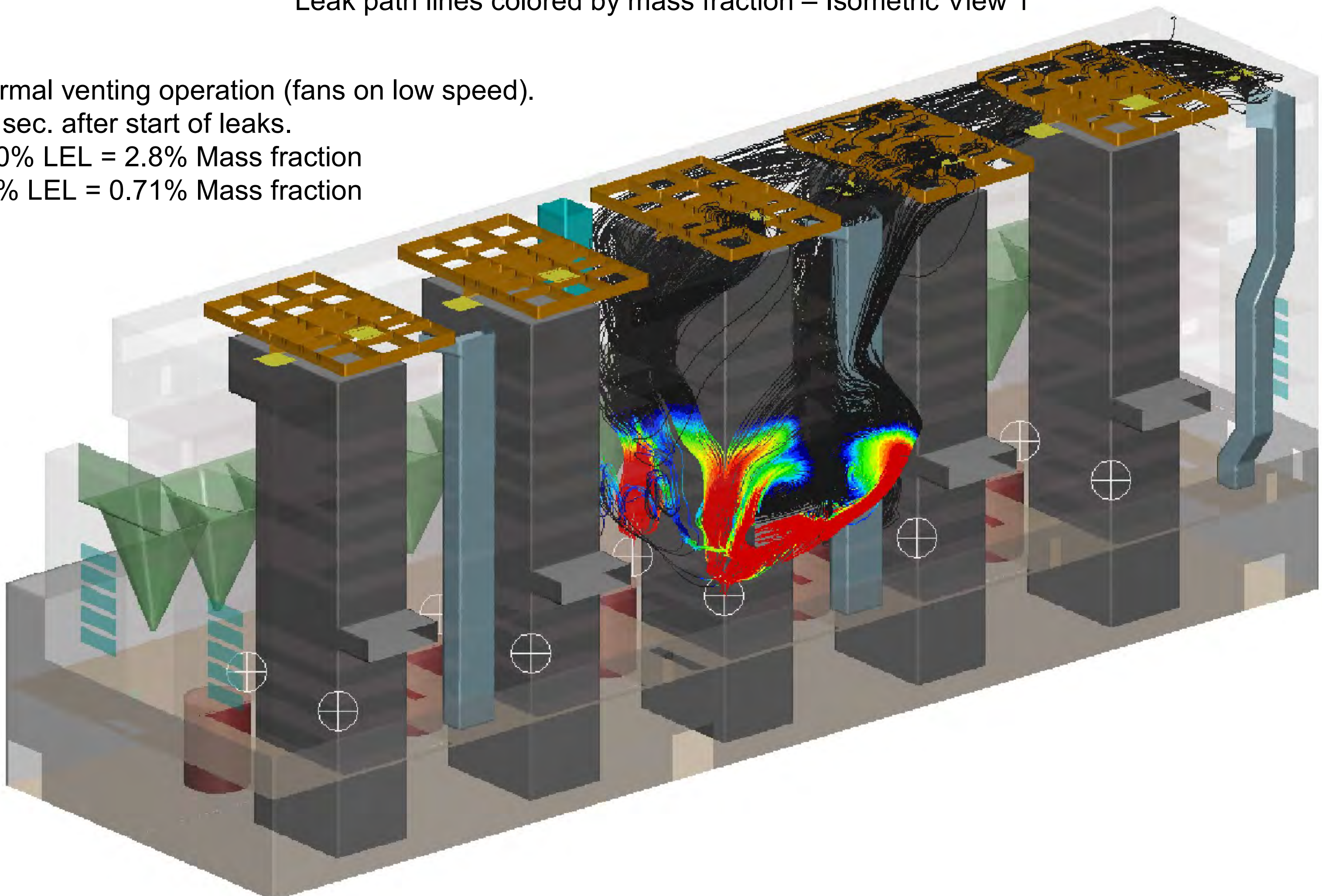
Case Study – Leak Tracking

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



Time = 30 sec.

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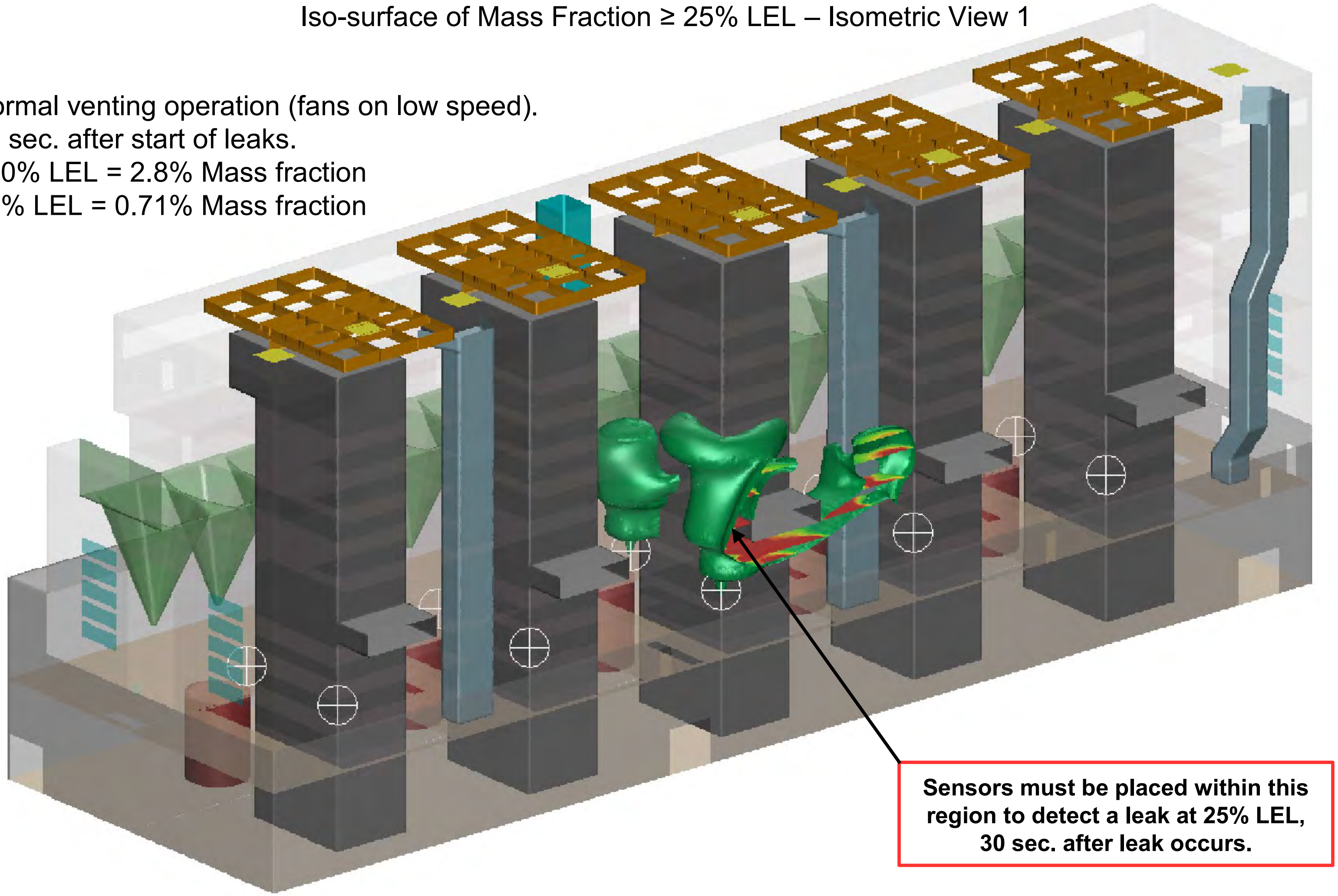
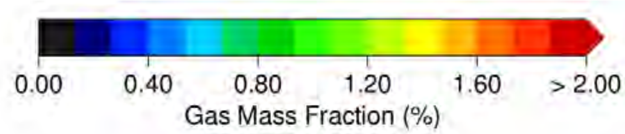
Case Study – Leak Tracking

Iso-surface of Mass Fraction ≥ 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



Time = 30 sec.



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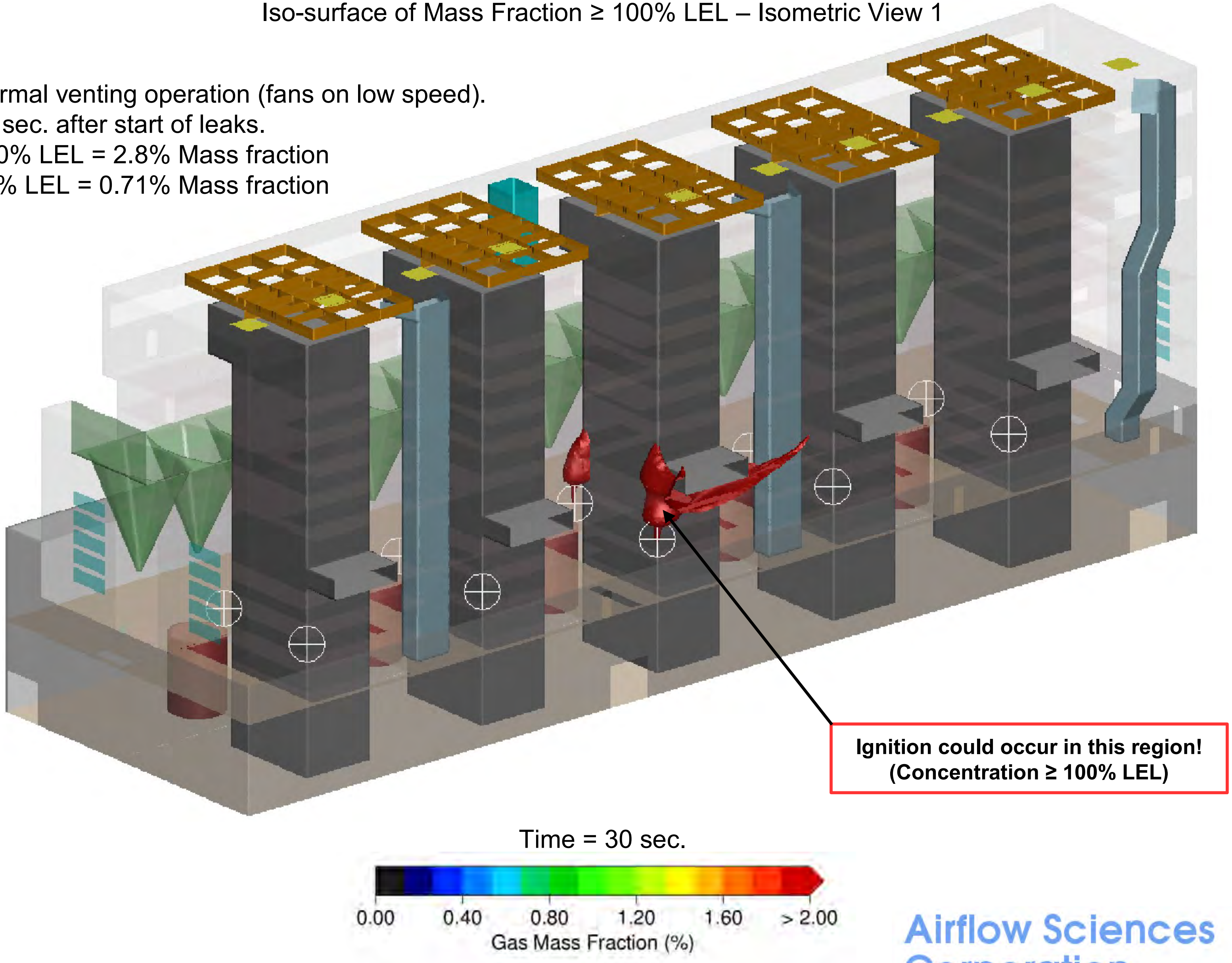
Case Study – Leak Tracking

Iso-surface of Mass Fraction ≥ 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



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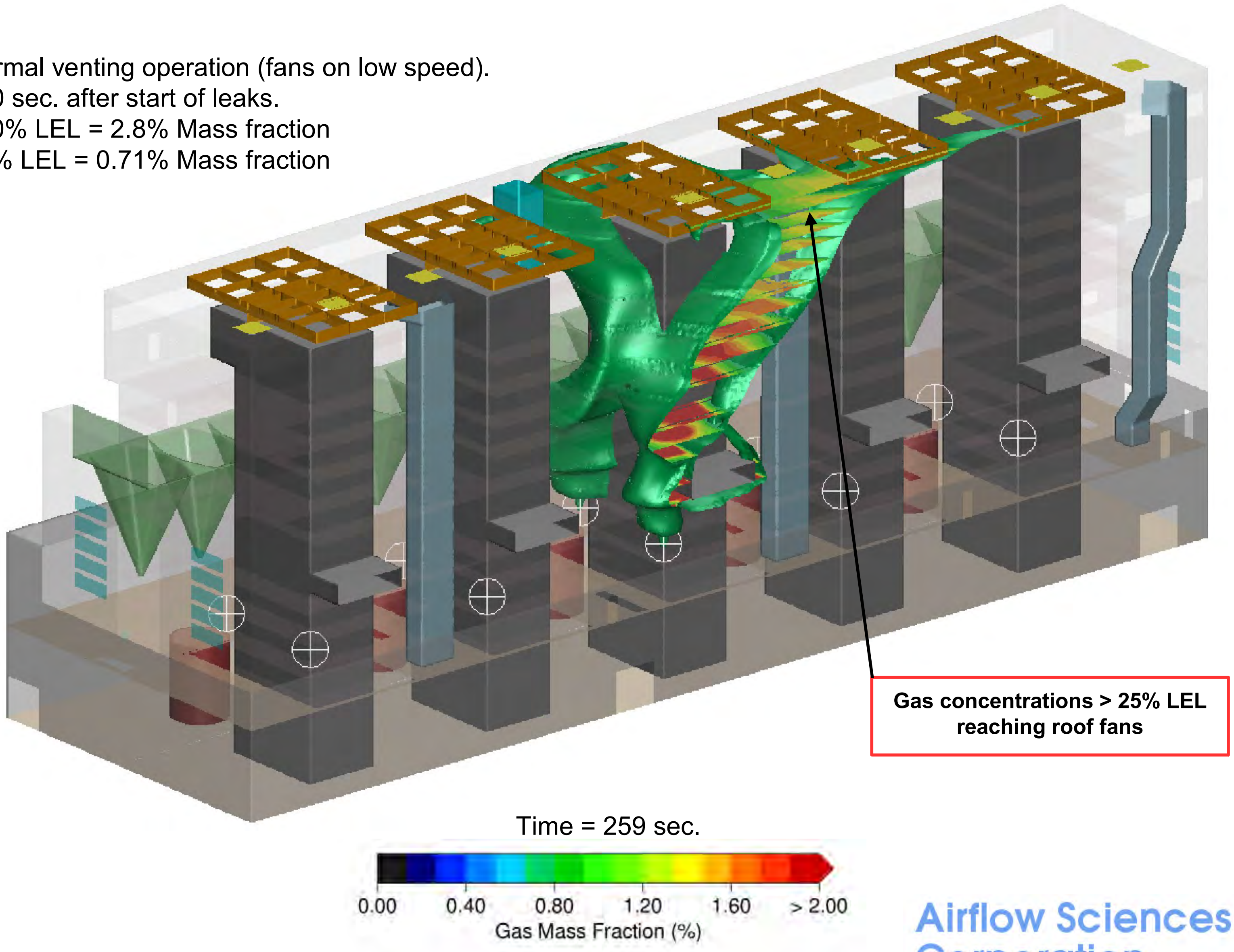
Case Study – Leak Tracking

Iso-surface of Mass Fraction ≥ 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



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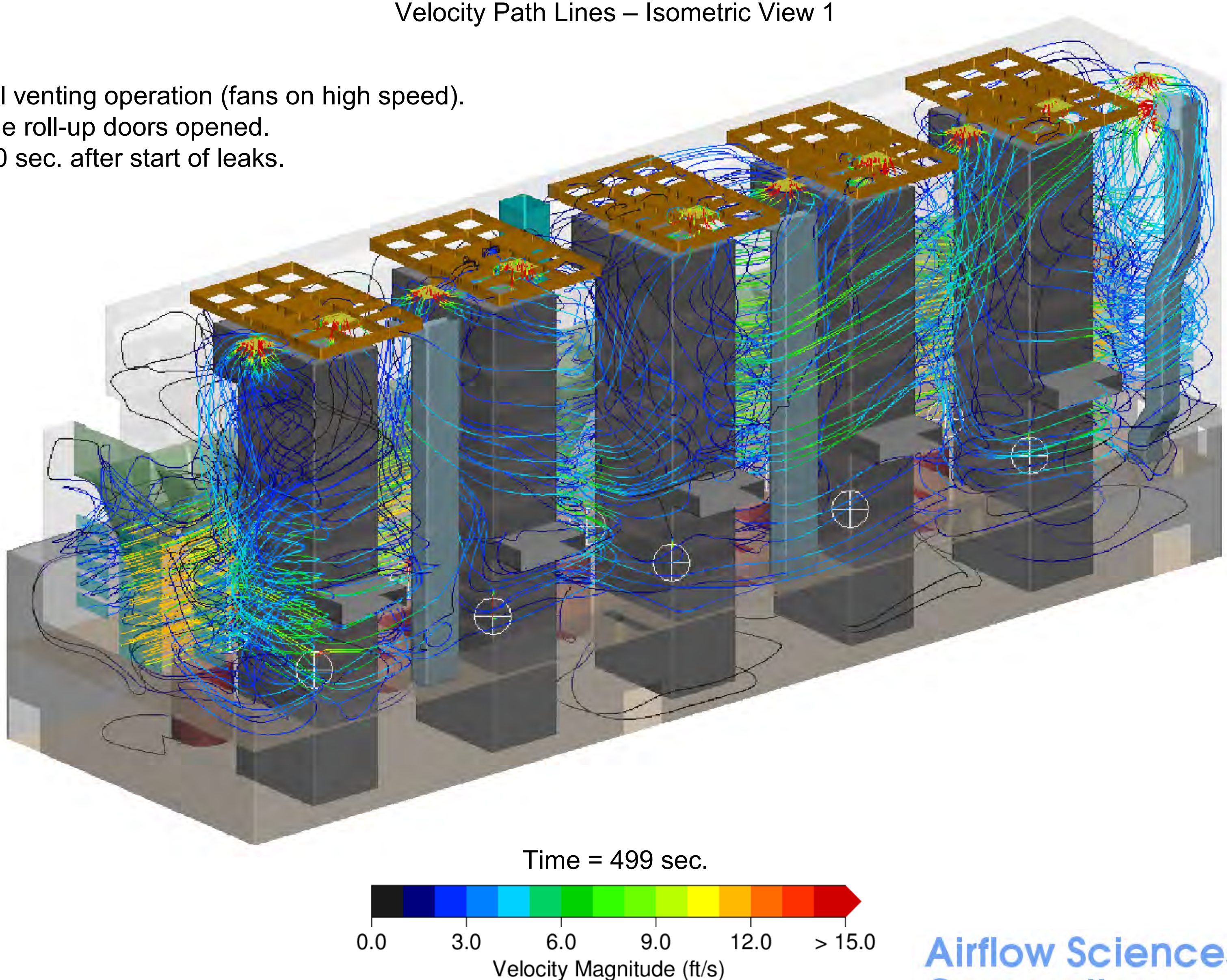
Case Study – Venting Flow

Velocity Path Lines – Isometric View 1

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



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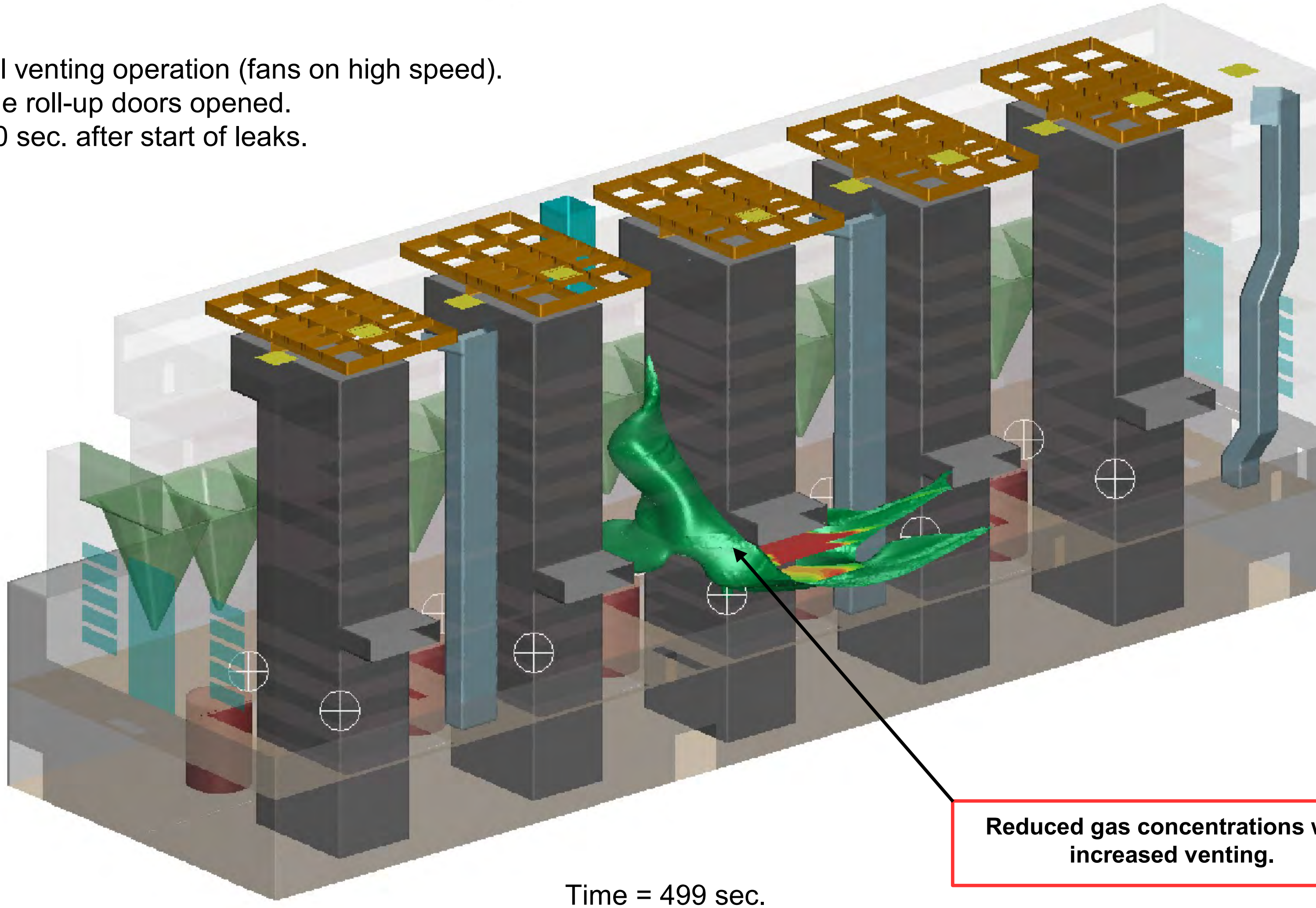
Case Study – Leak Tracking

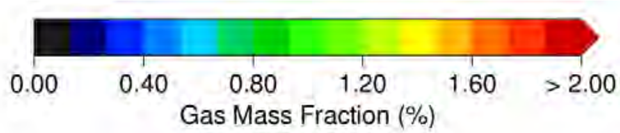
Iso-surface of Mass Fraction ≥ 25% LEL – Isometric View 1

- 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.



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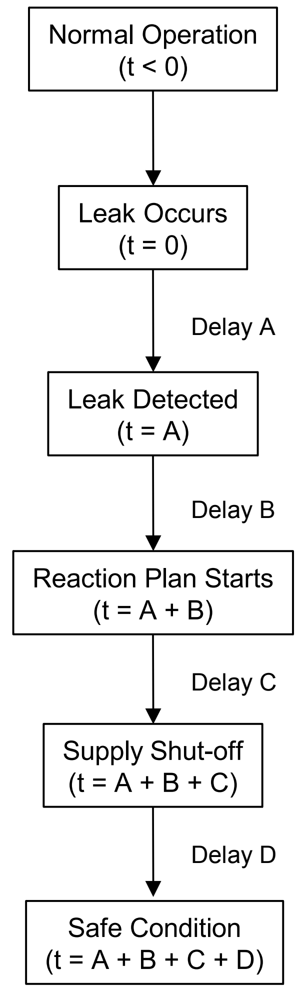
Case Study – Reaction Sequence

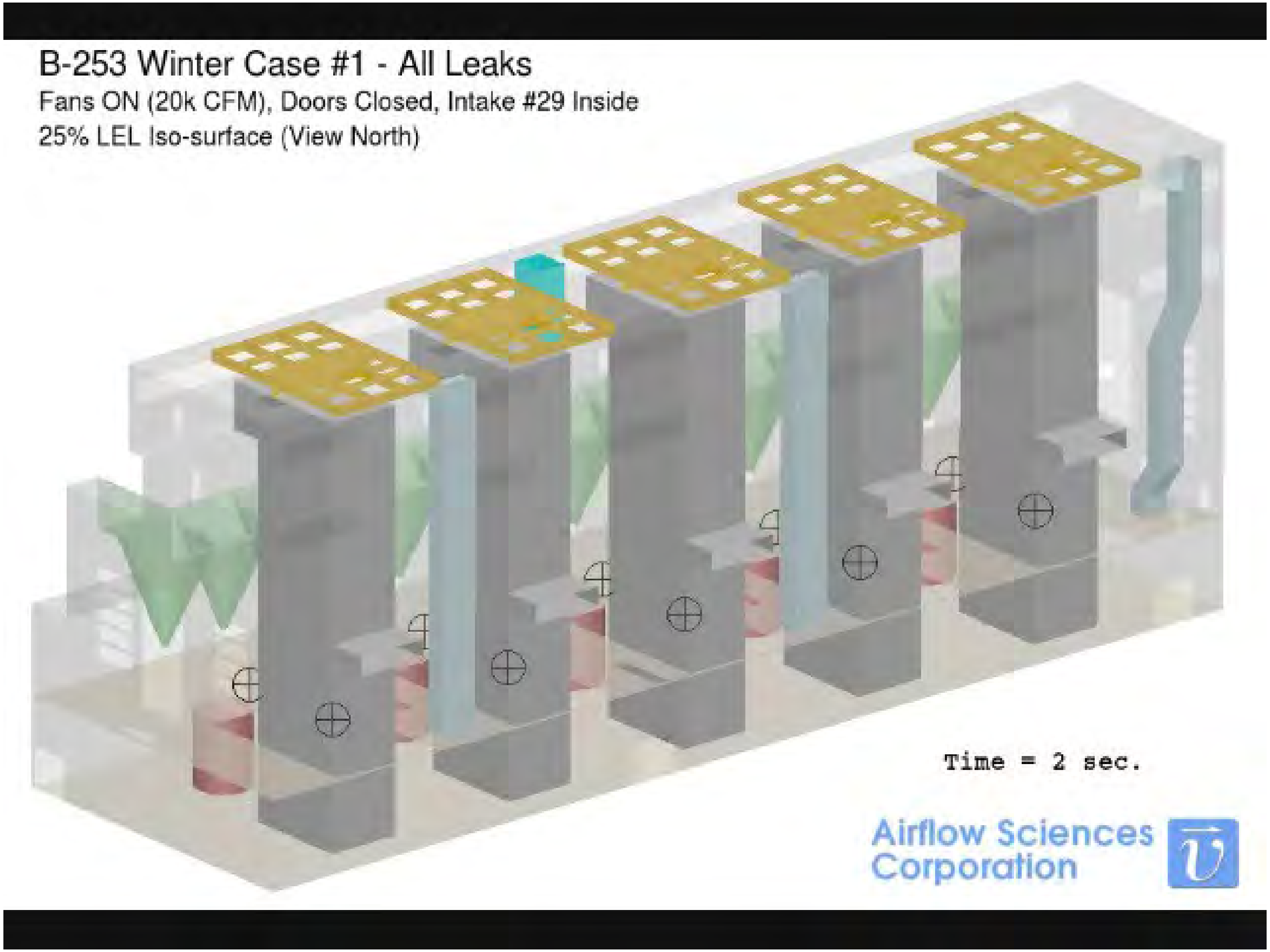
Typical Leak Reaction Plan (Timeline)



Case Study – Reaction Sequence

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

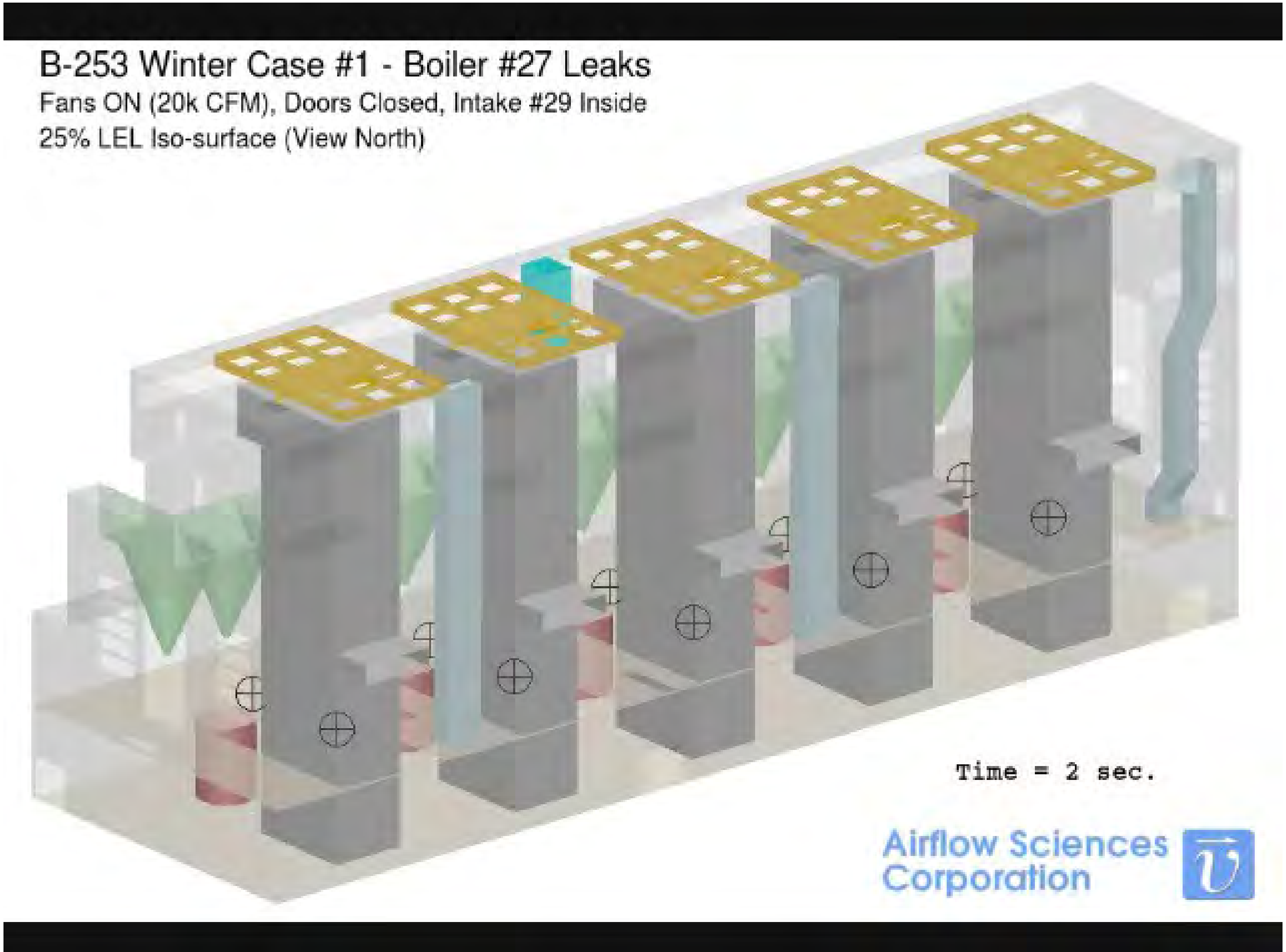
10 Simultaneous Leaks



Case Study – Reaction Sequence

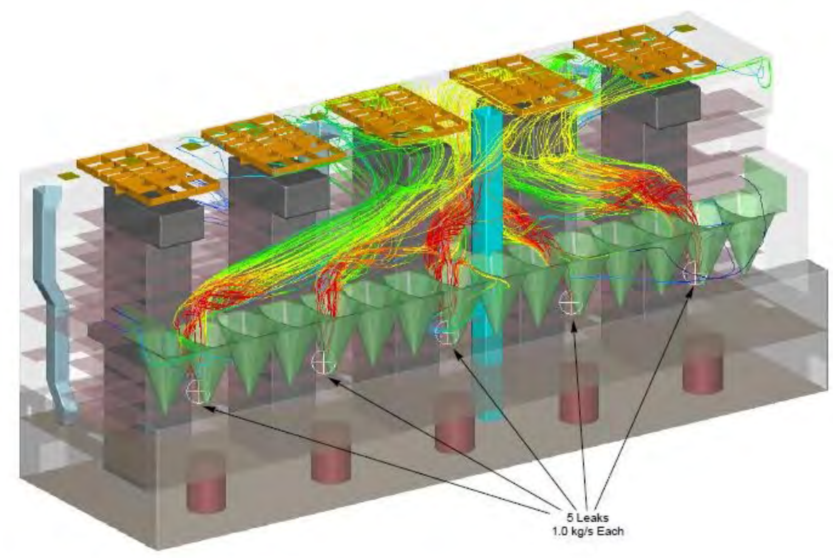
Evolution of iso-surface (mass Fraction ≥ 25% LEL) over full reaction sequence.

2 Leaks at Center Boiler



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

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Questions?

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