NRC Fire Modeling Research

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Outline

- **Objectives**
- **Organization**
- **Status and Results**
- **Future Efforts**

Objectives

- **Determine capabilities and limitations of fire models for NPP fire scenarios**
- **Conduct benchmarking and validation exercises**
- **Evaluate NIST codes for NRC use**
- **Quantify uncertainties in model predictions**

Organization and Collaboration

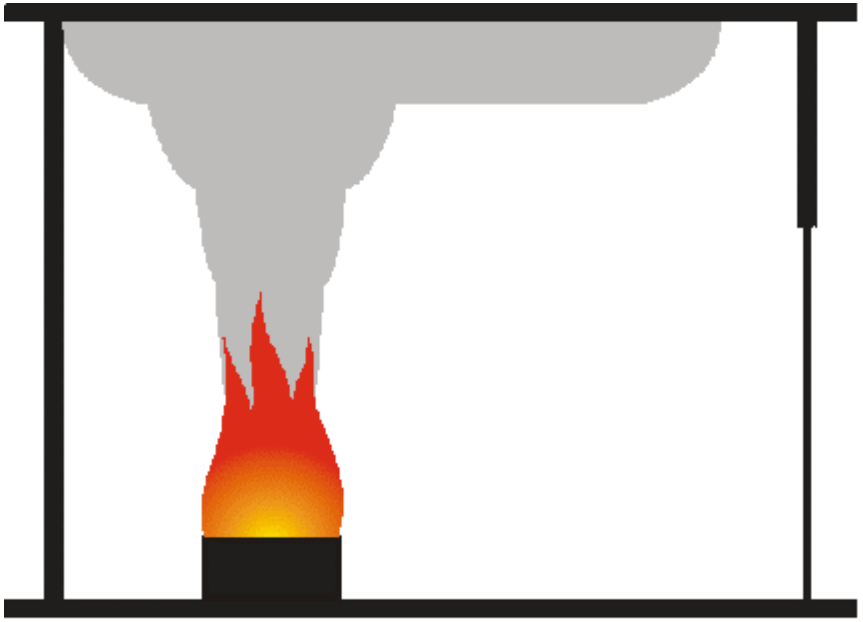
- **NRC/NIST MOU**
  - **Evaluate and validate NIST fire codes for use in NRC's regulatory framework**
- **NRC/EPRI MOU**
  - **Develop library of fire scenarios**
  - **Define scenarios and conduct analyses**
  - **EPRI plans to develop fire modeling guide**

International Collaborative Fire Model Project (ICFMP)

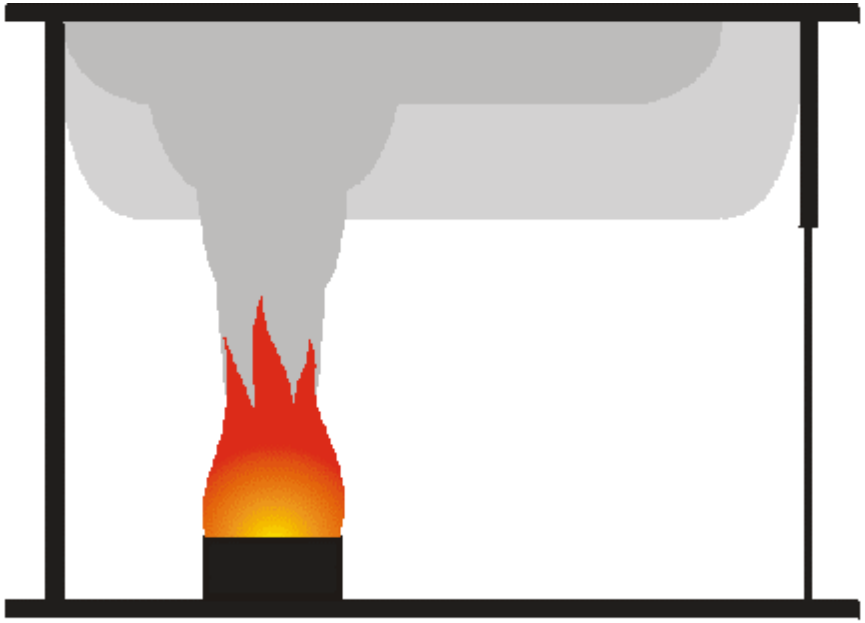
- **Project established by NRC in 10/99**
- **Experts from 22 organizations in nuclear and building industries**
- **Share information and resources**
- **Conduct benchmarking and validation exercises**
- **Document information and findings in technical reference reports**

Results to Date

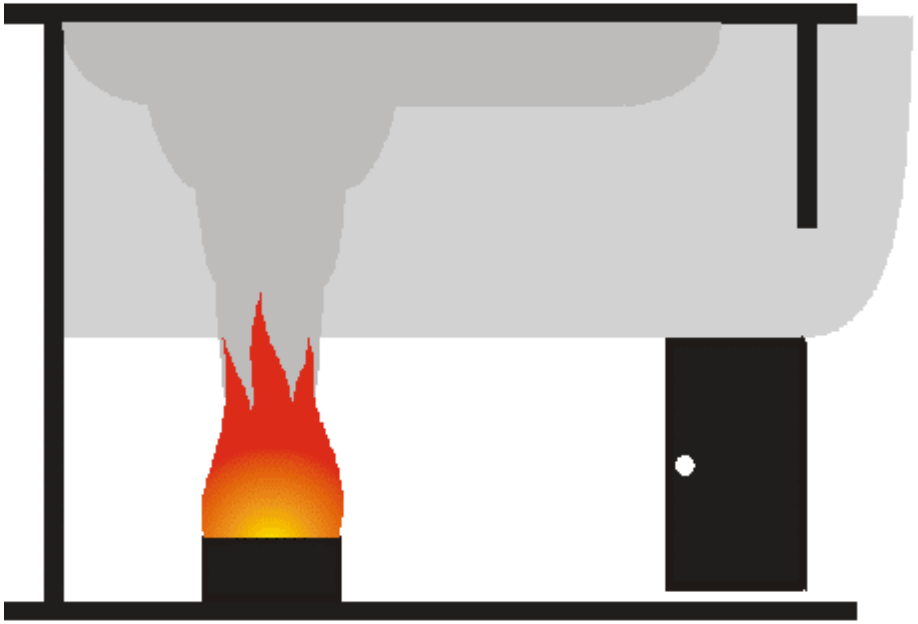
- **Benchmark Exercise No. 1**
  - **Analyses completed by 6 organizations**
  - **Expect final report to be published in October, 01**
- **Proposal for Benchmark Exercise No. 2 developed**
- **Validation database report issued**
- **Proposal for international blind validation exercises being developed**



Stage 1. Fire plume/ceiling jet period



Stage 2. Enclosure smoke filling period



Stage 3. Preflashover vented period

Stage 4. Postflashover vented period

Types of Fire Models

- **Empirical models and approximations suitable for screening calculations**
- **Zone models**
- **Field (CFD) models**

Models Suitable for Screening

- **Calculations can typically be done by hand or using spreadsheets**
- **Empirical models (e.g., NRR worksheets)**
- **Fire models in FIVE methodology**

Zone Models

- **Empirically-based plume correlations used to pump mass and energy between hot and cold layers**
- **Apply conservation of mass and energy to hot and cold gas layers**
- **Bernoulli equation to model vent flows**

Computational Fluid Dynamics (CFD or Field Models)

- **Apply conservation of mass, energy, and momentum to a large number of computational cells**
- **Solves low-speed, thermally-driven flow with emphasis on smoke and heat transport**

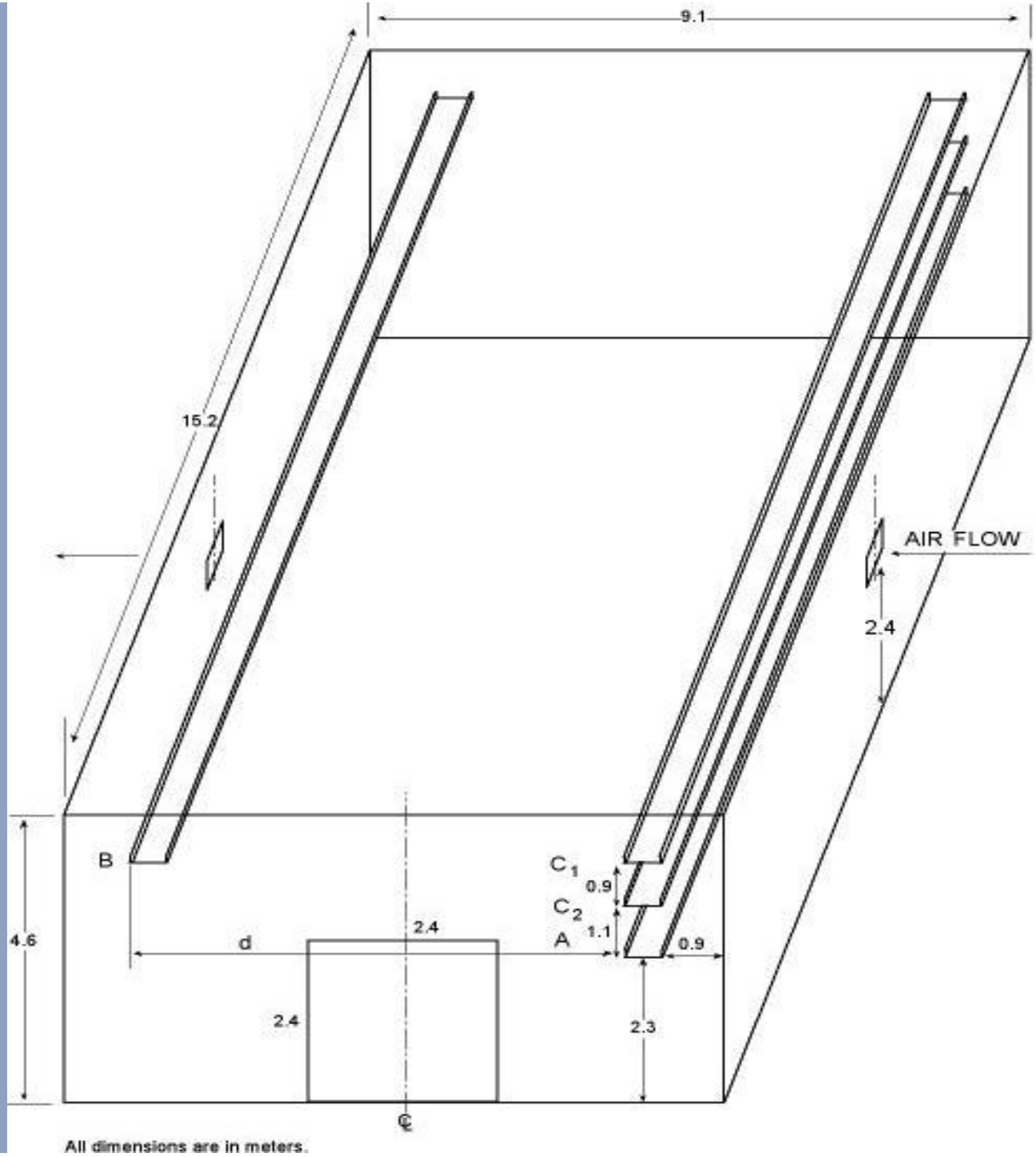
NIST Fire Codes

- **CFAST (the Consolidated model for Fire And Smoke Transport) uses the zone model approach**
- **FDS (Fire Dynamics Simulator) is a newly developed CFD model**

Benchmark Exercise No. 1: Cable Tray Fires

Determine capabilities and limitations of models to simulate:

- **Ignition of cable trays with transient fire sources**
- **Damage of cable tray by a fire in a redundant/separated cable tray**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All dimensions are in meters.

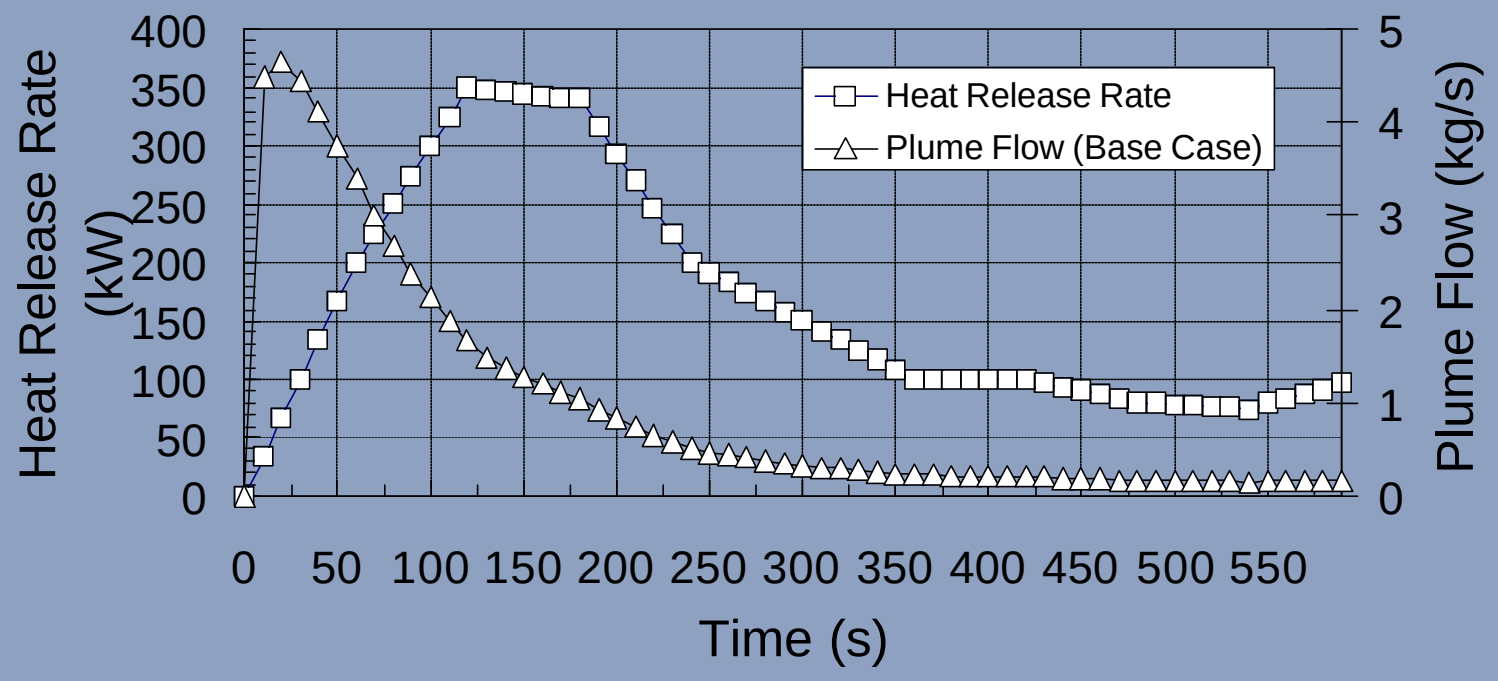
Major Sub-Models Used in CFAST

- **Combustion chemistry (O_2 and species)**
- **Plumes and layers**
- **Vent Flow (including forced ventilation)**
- **Heat transfer, especially radiation and convection to target**

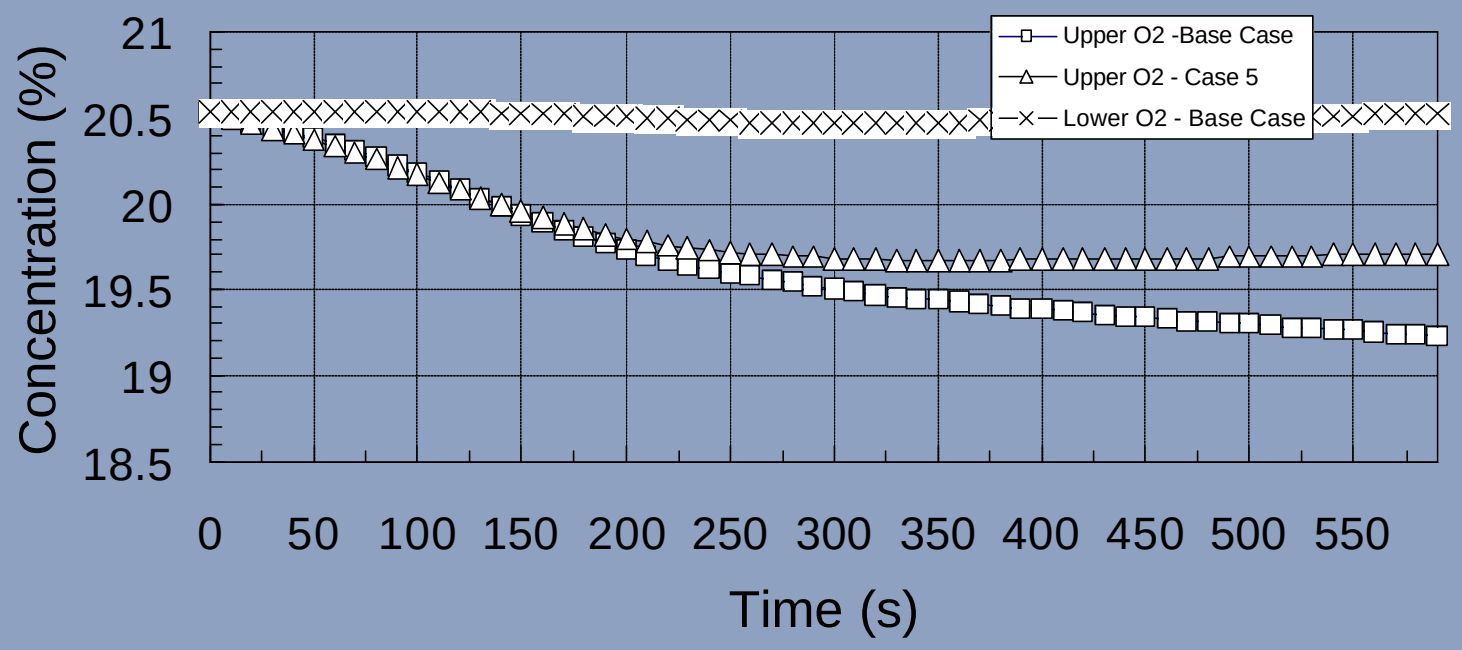
Summary of Cases for Part I

	Door	Ventilation System
Base Case	Closed	Off
Case 4	Open	Off
Case 5	Closed	On

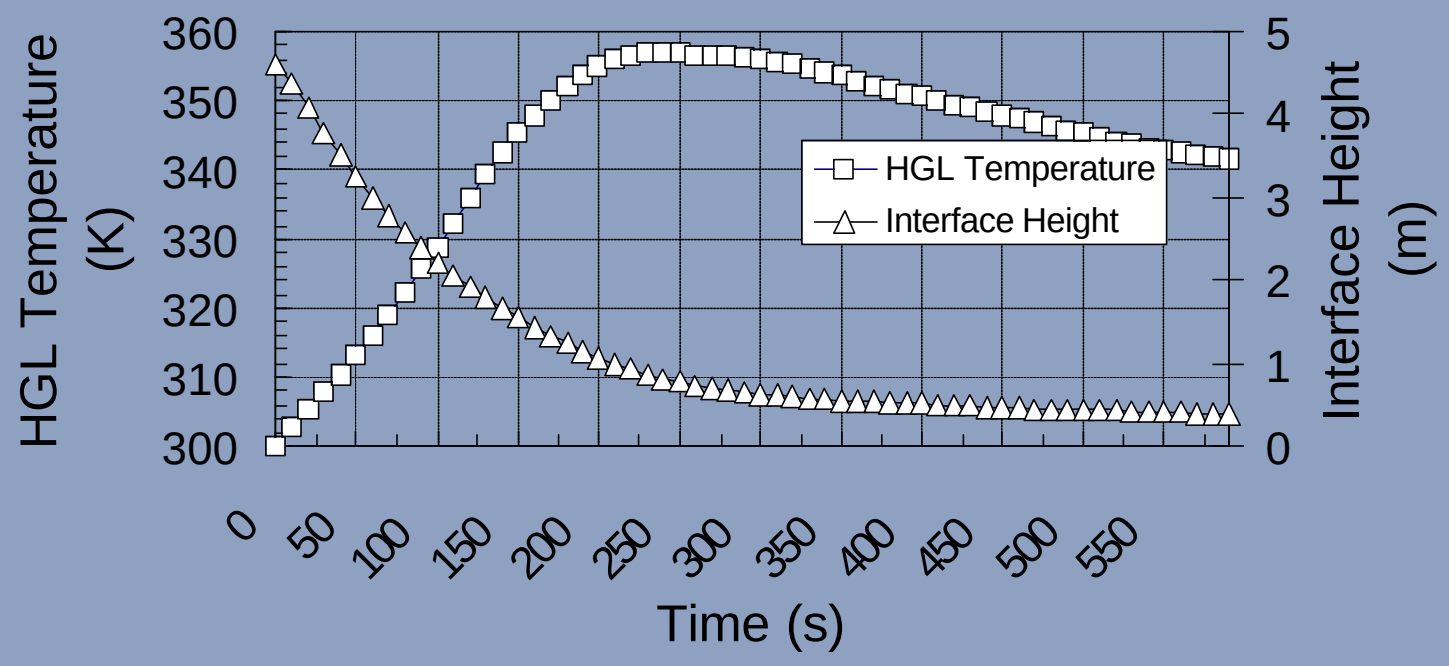
Heat Release Rate & Plume Flow



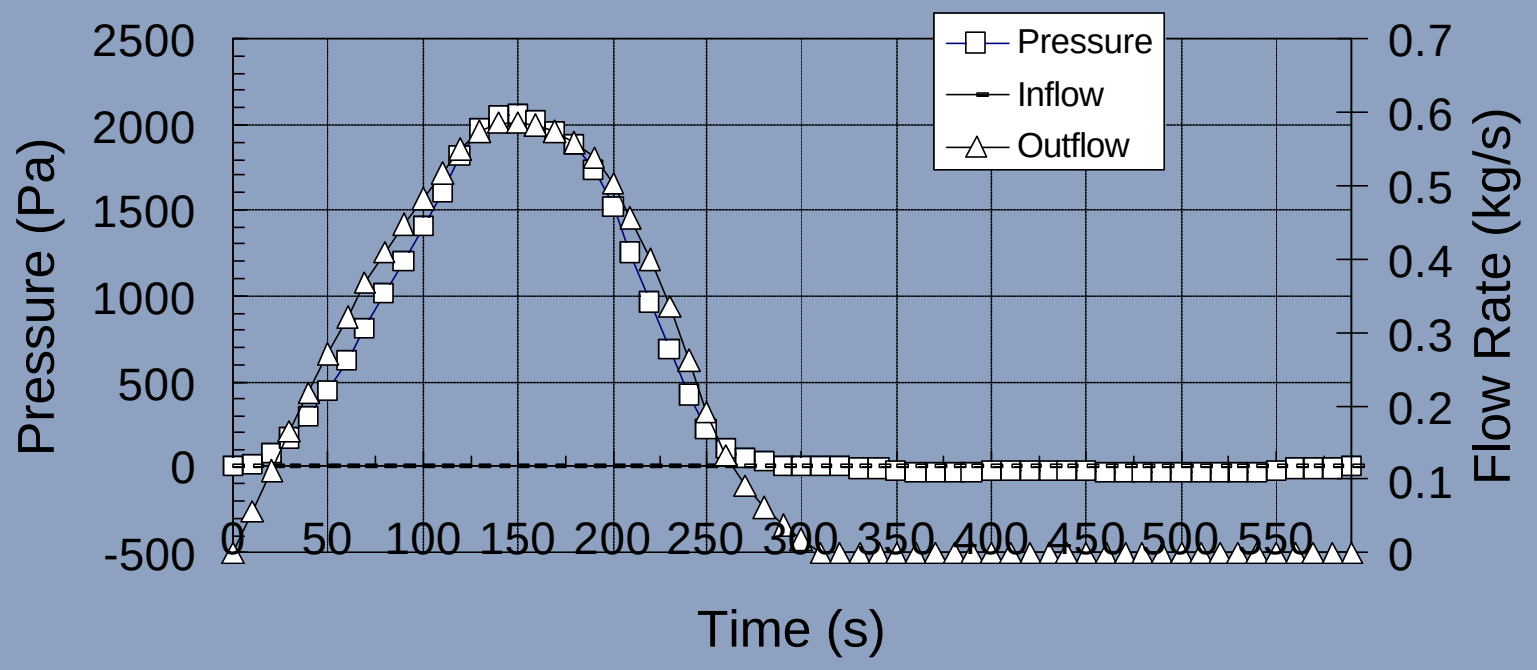
Oxygen Concentrations



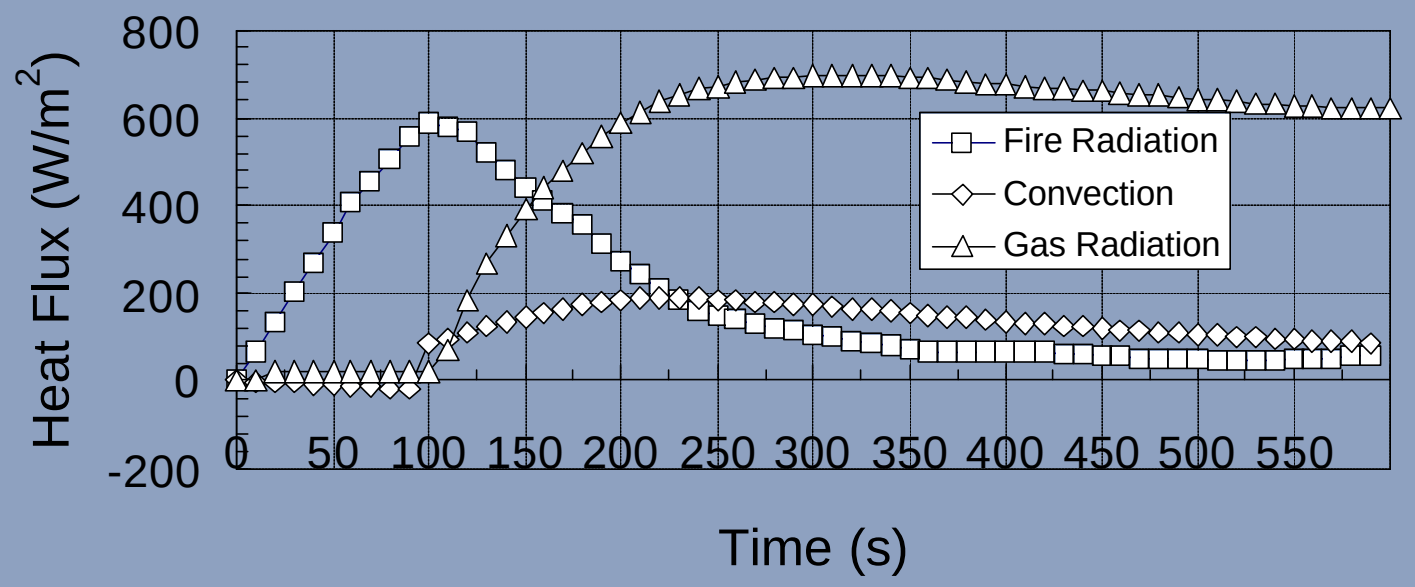
Hot Gas Layer Development Base Case



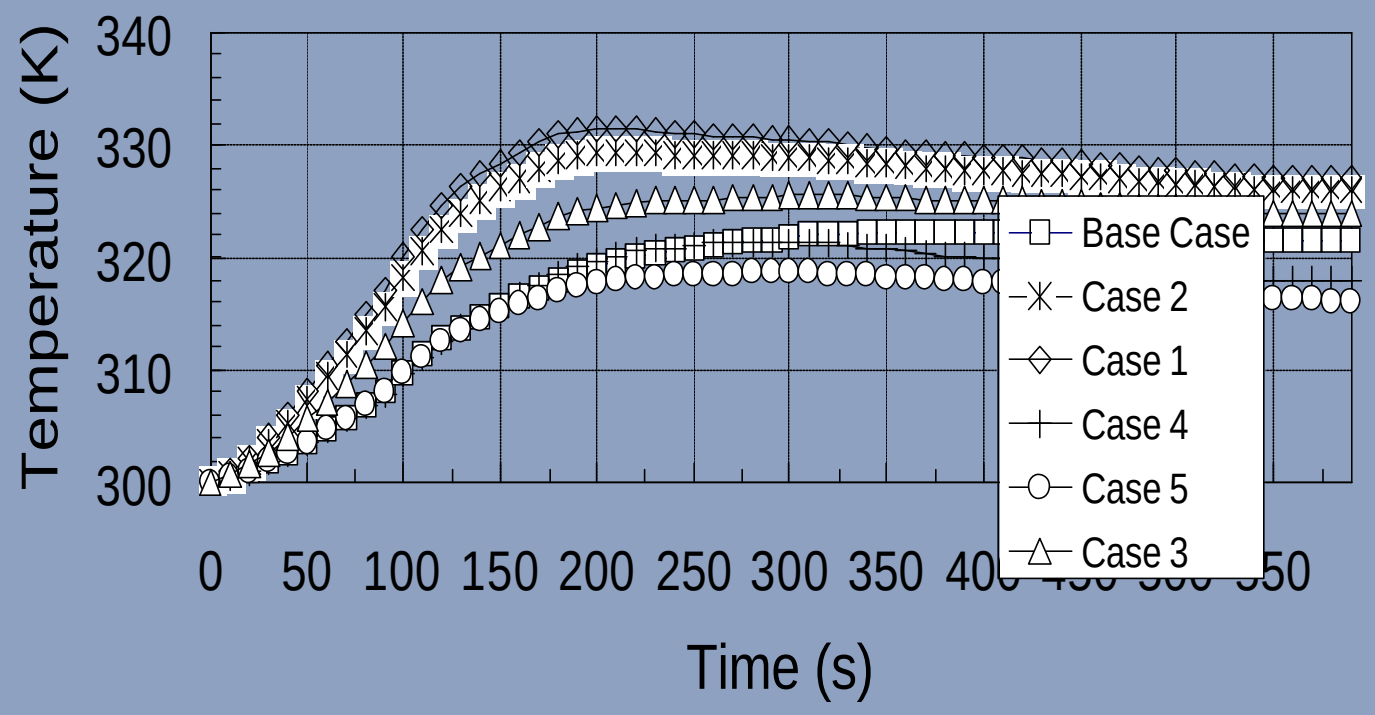
Pressure and Vent Flow Development – Base Case



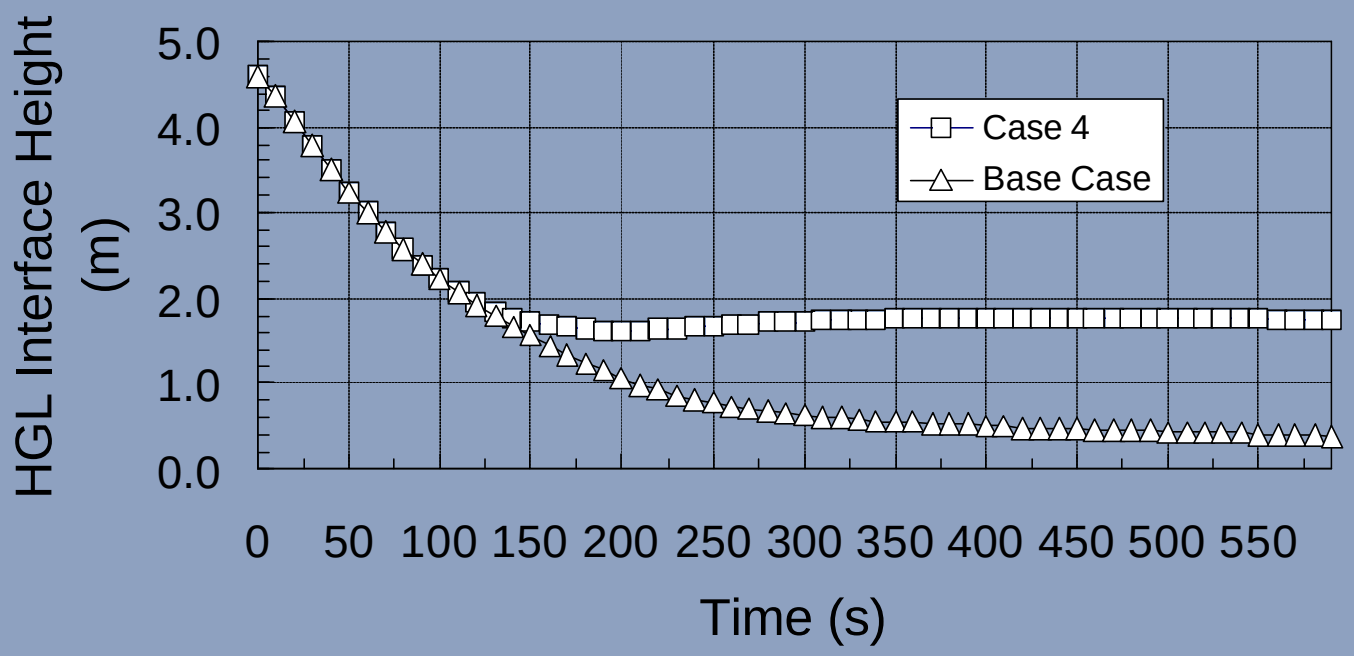
Heat Fluxes – Base Case



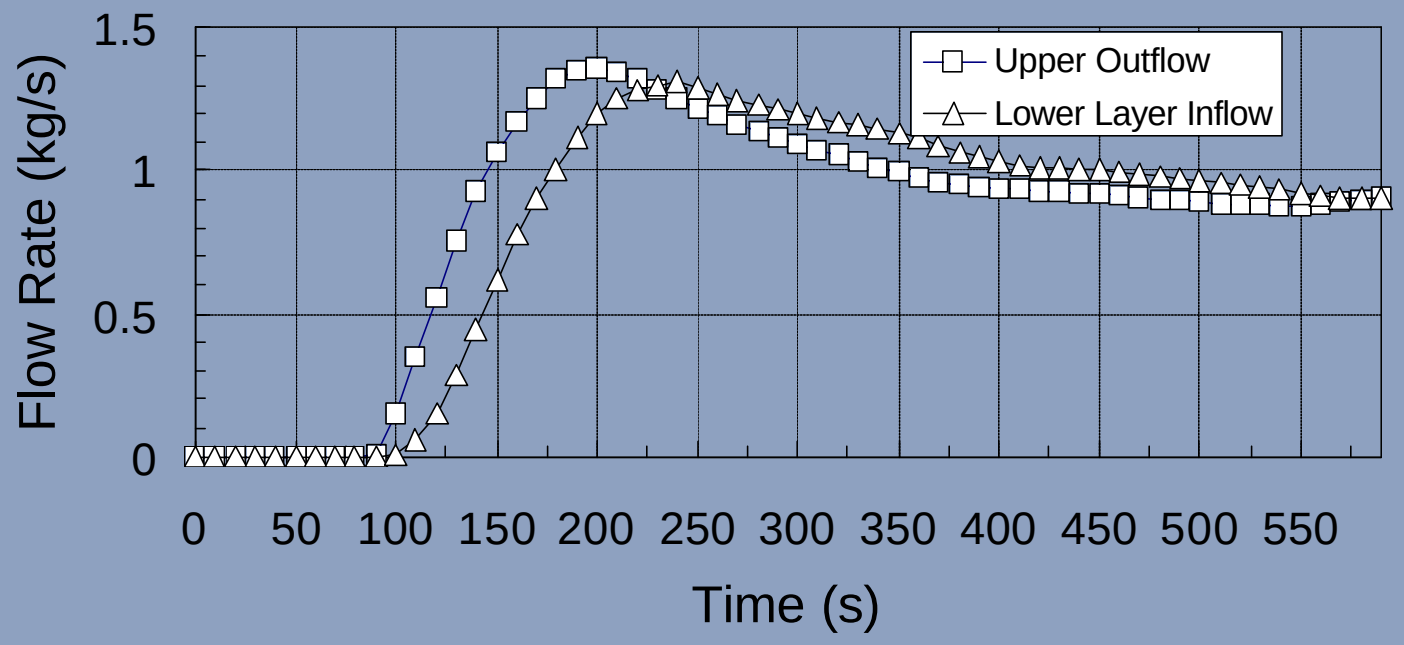
Target Surface Temperatures



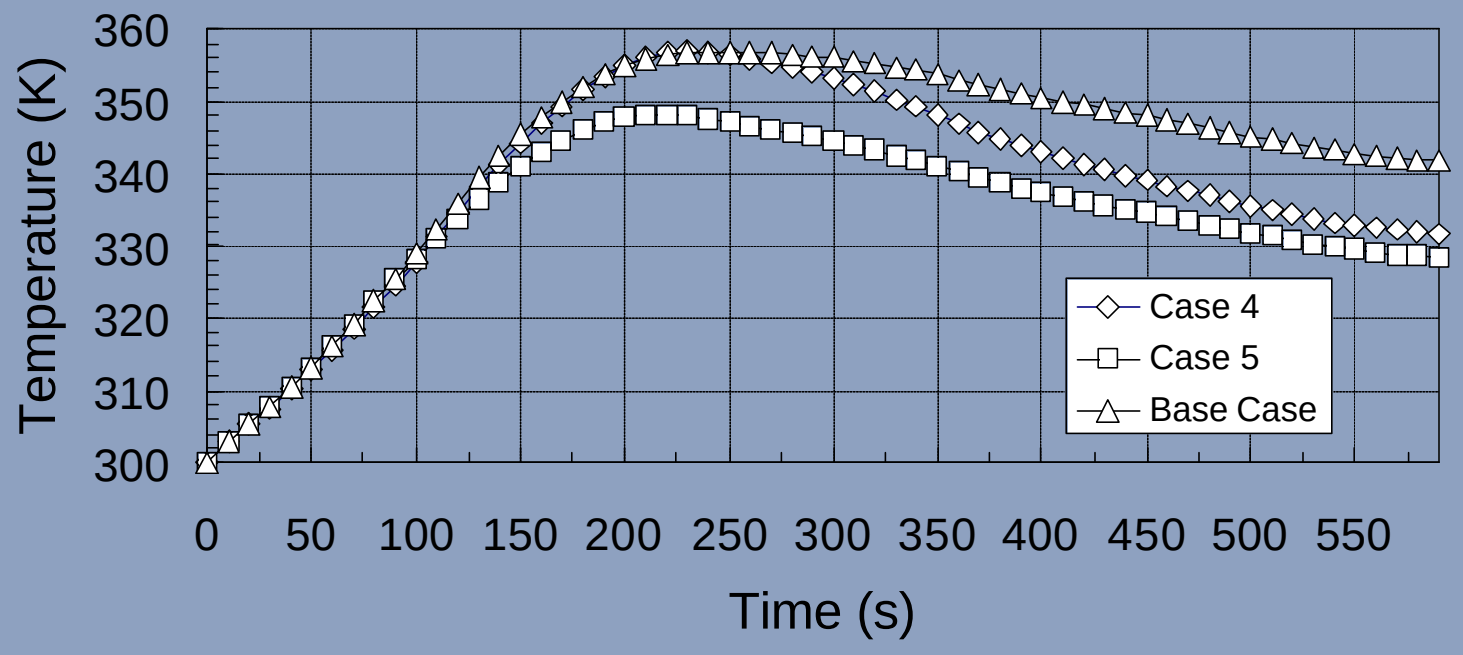
Hot Gas Layer Development Case 4



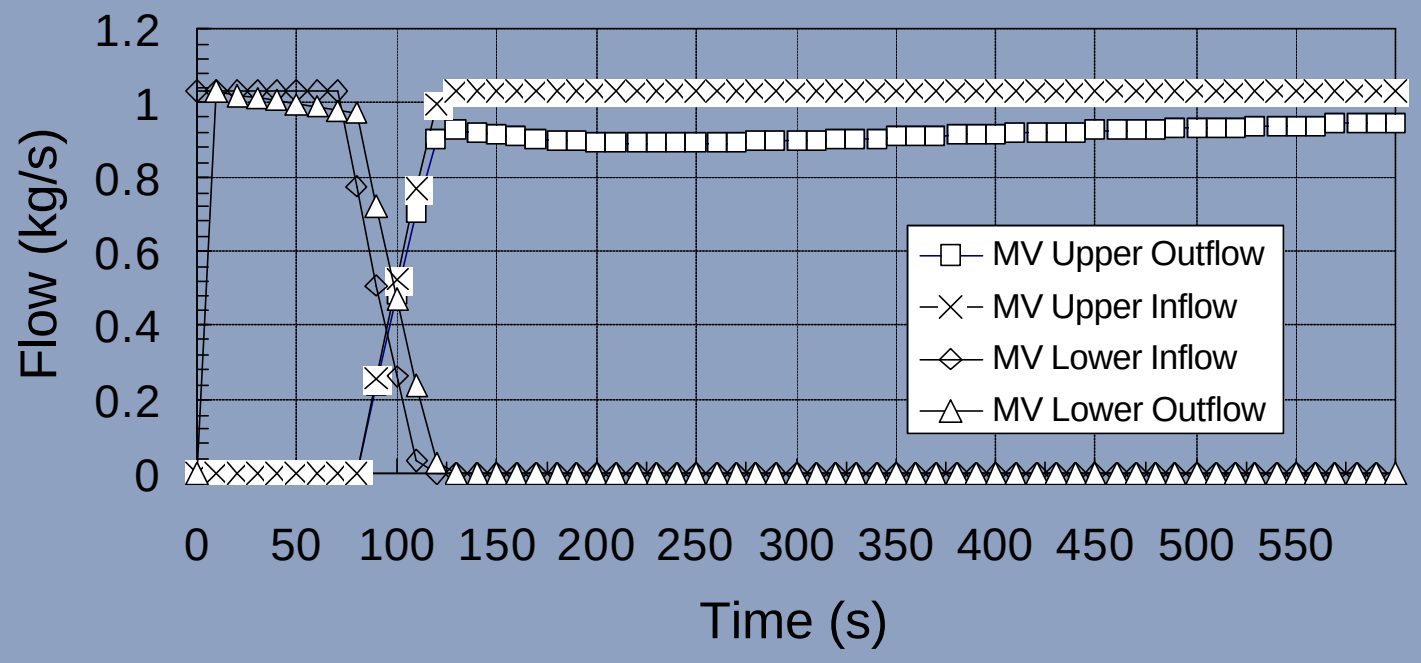
Door Flows – Case 4

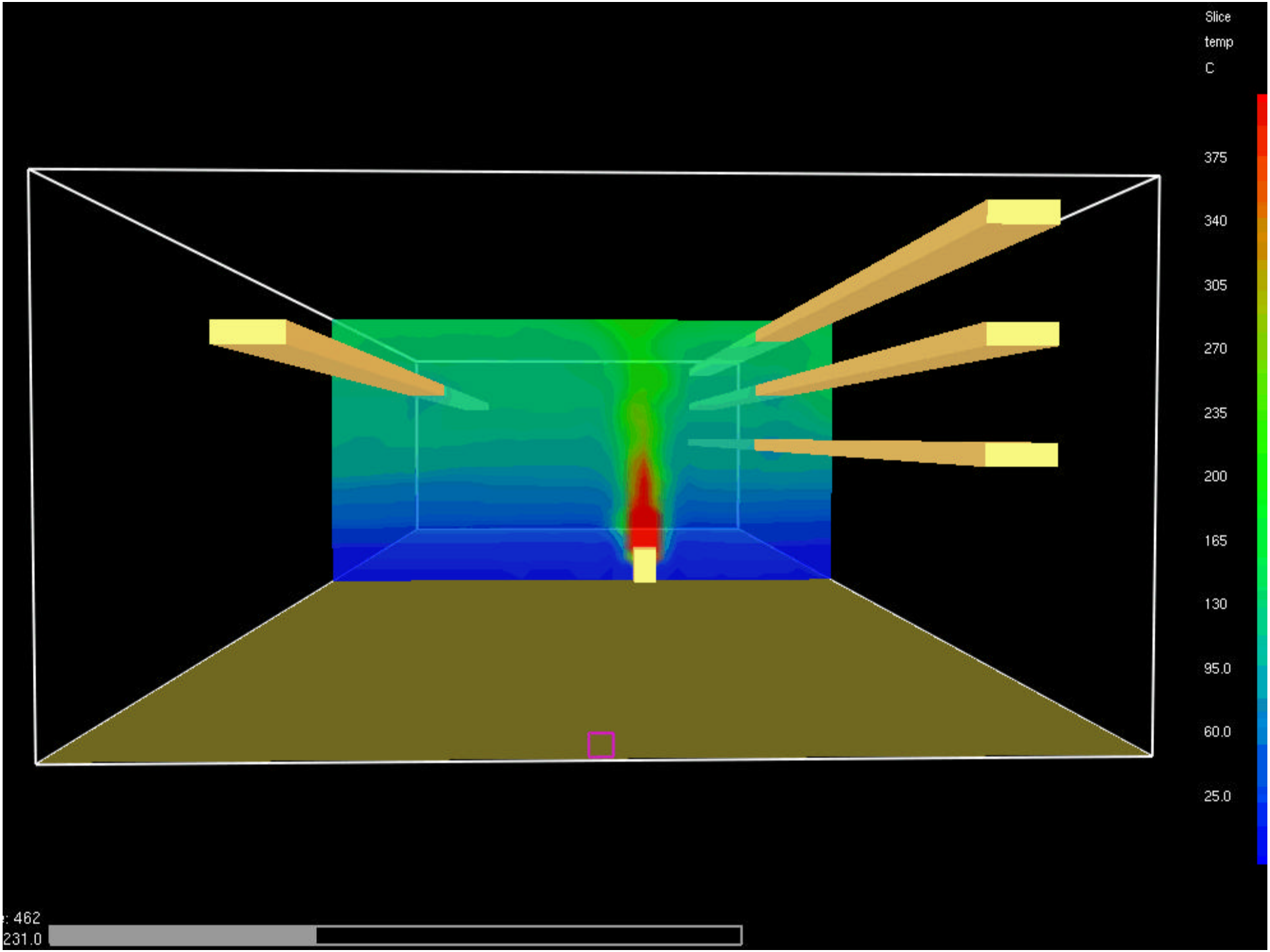


Hot Gas Layer Temperature



Mechanical Ventilation Flows Case 5

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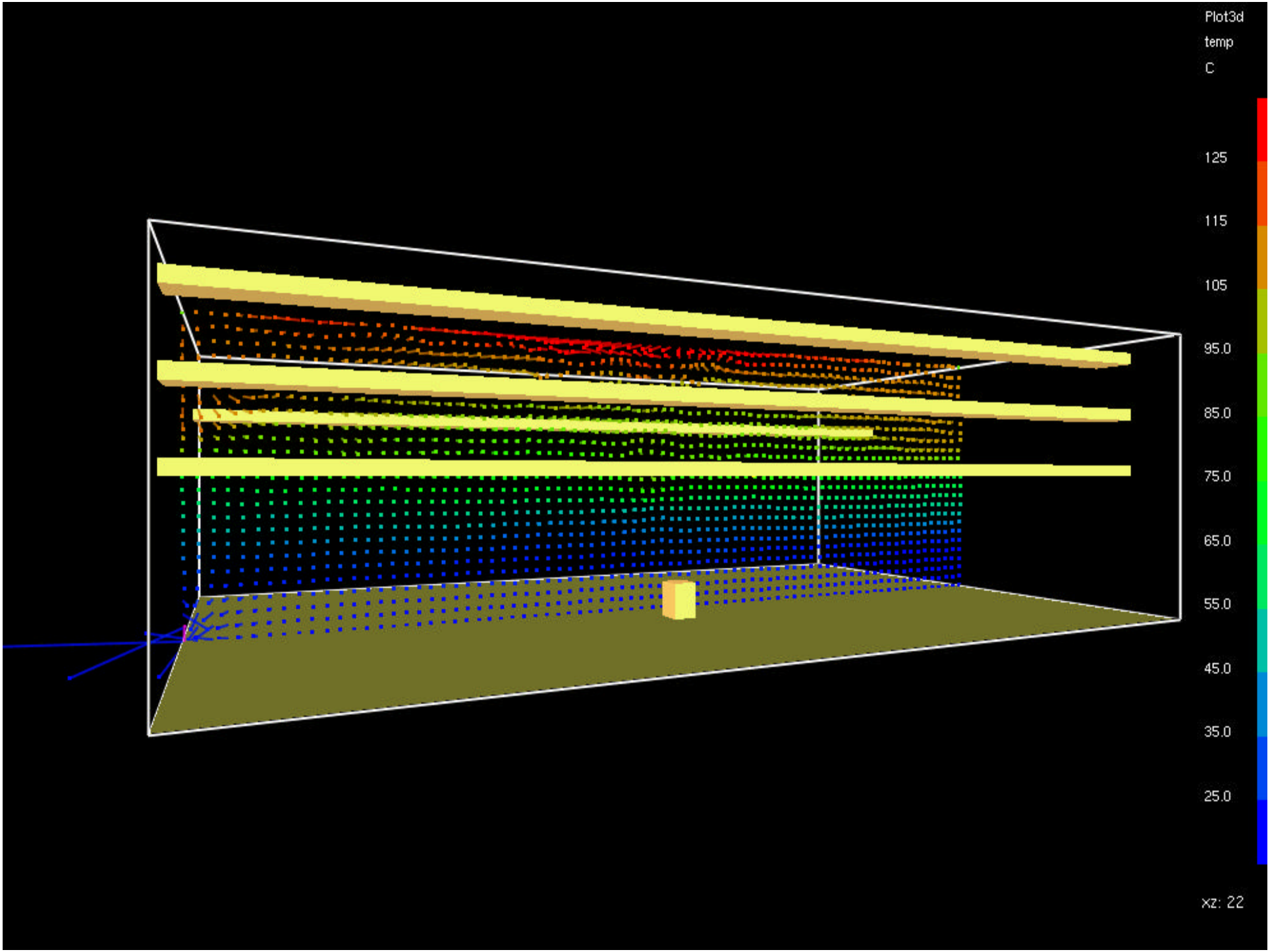
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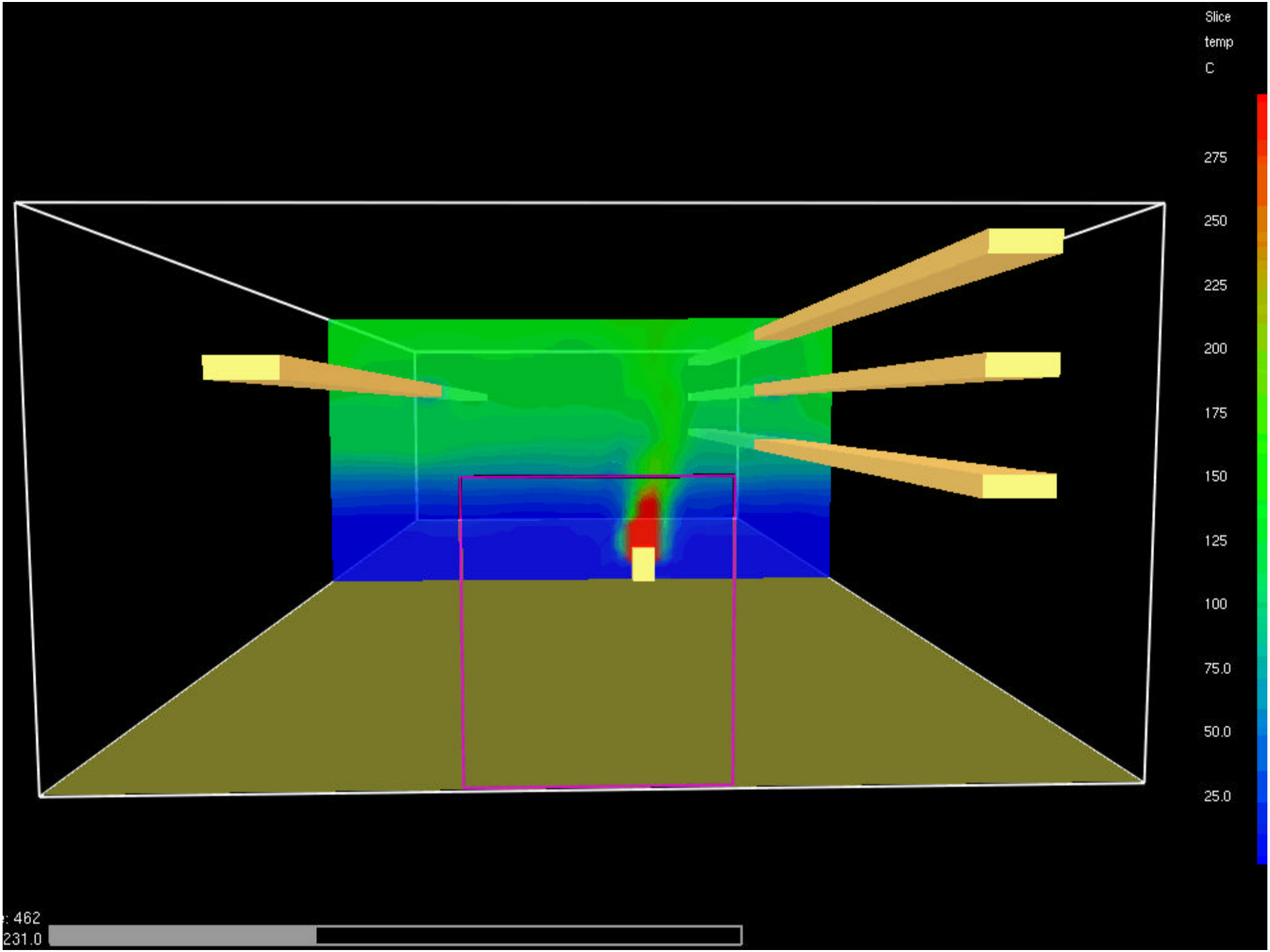
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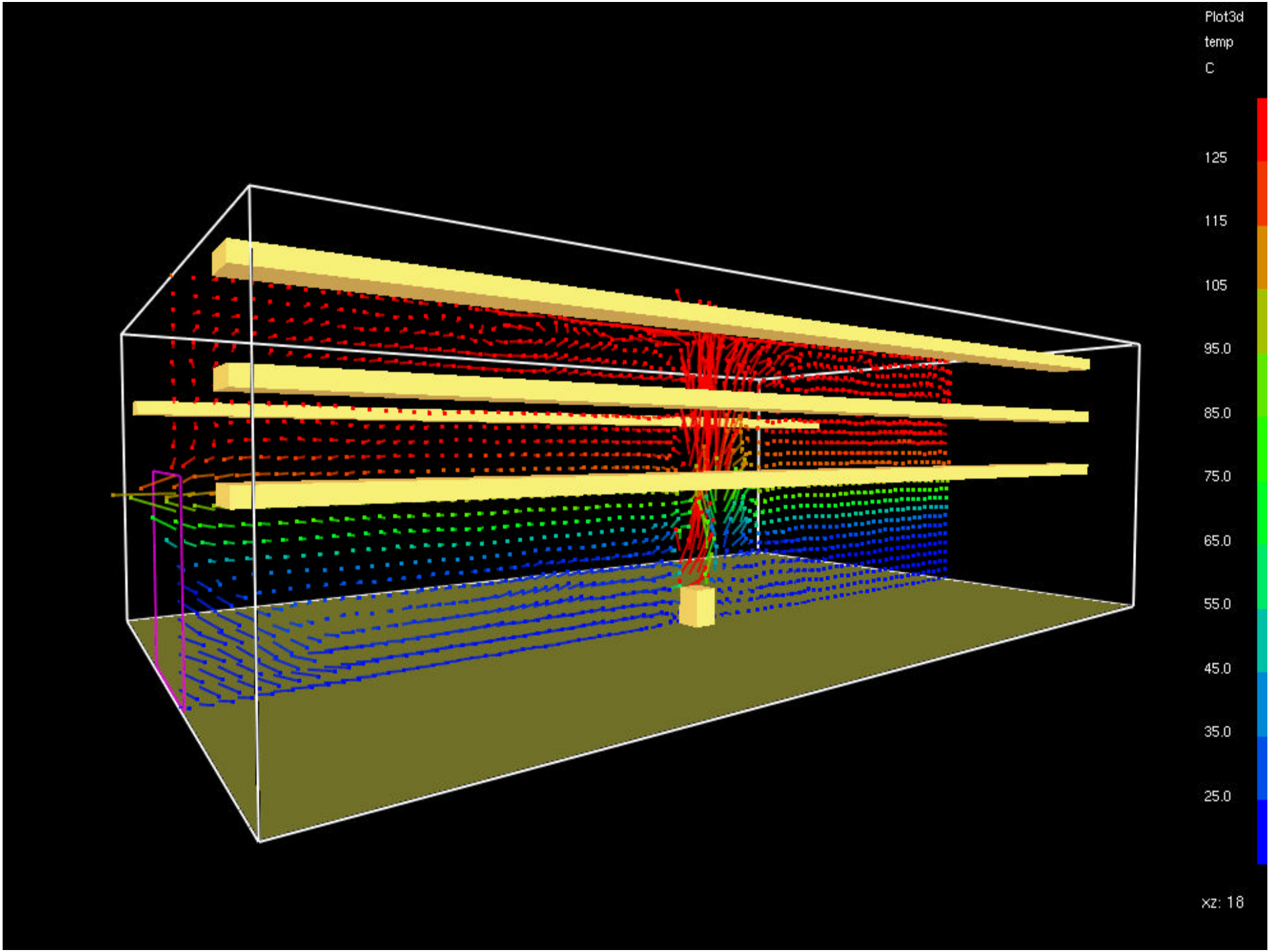
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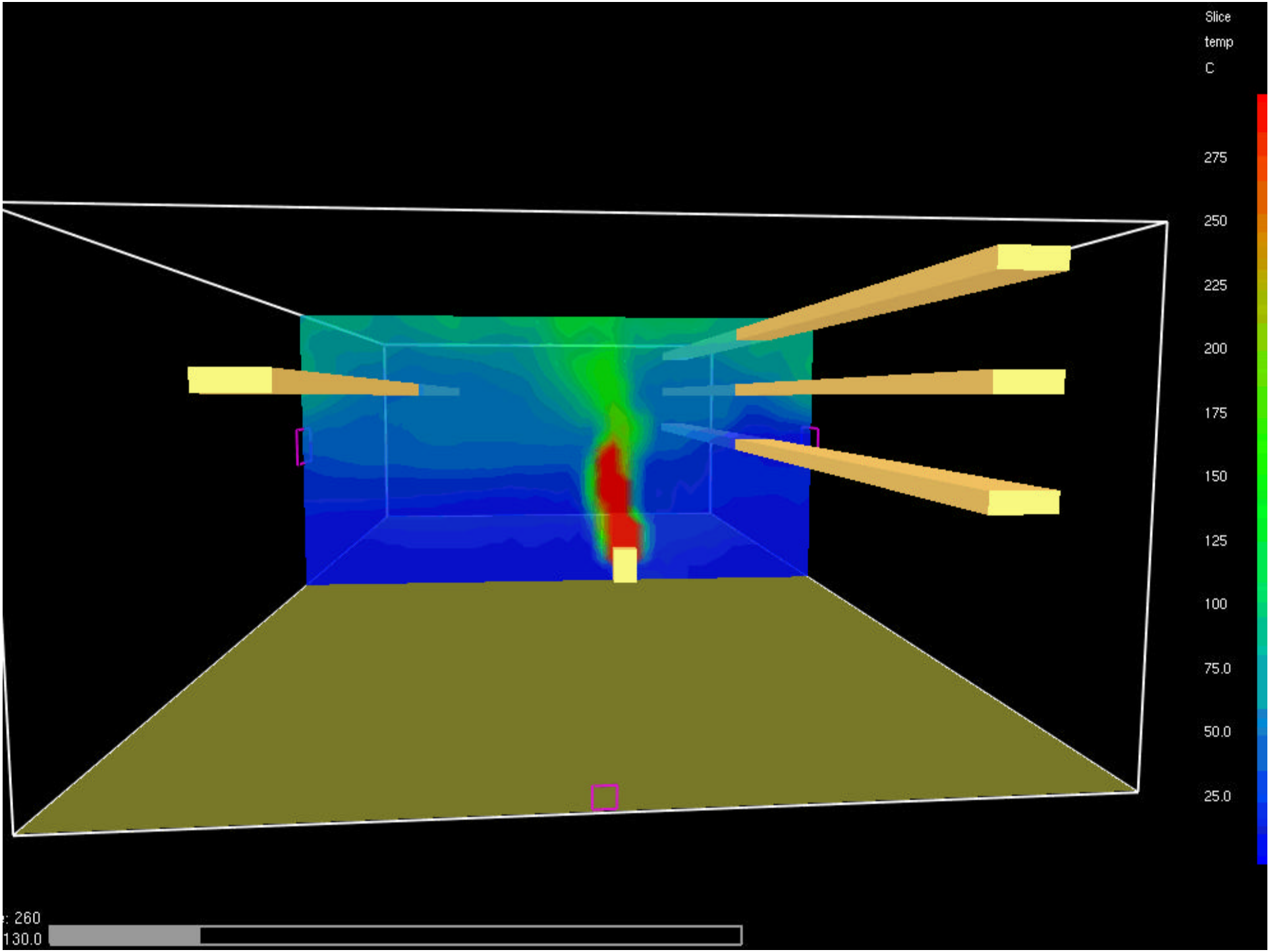
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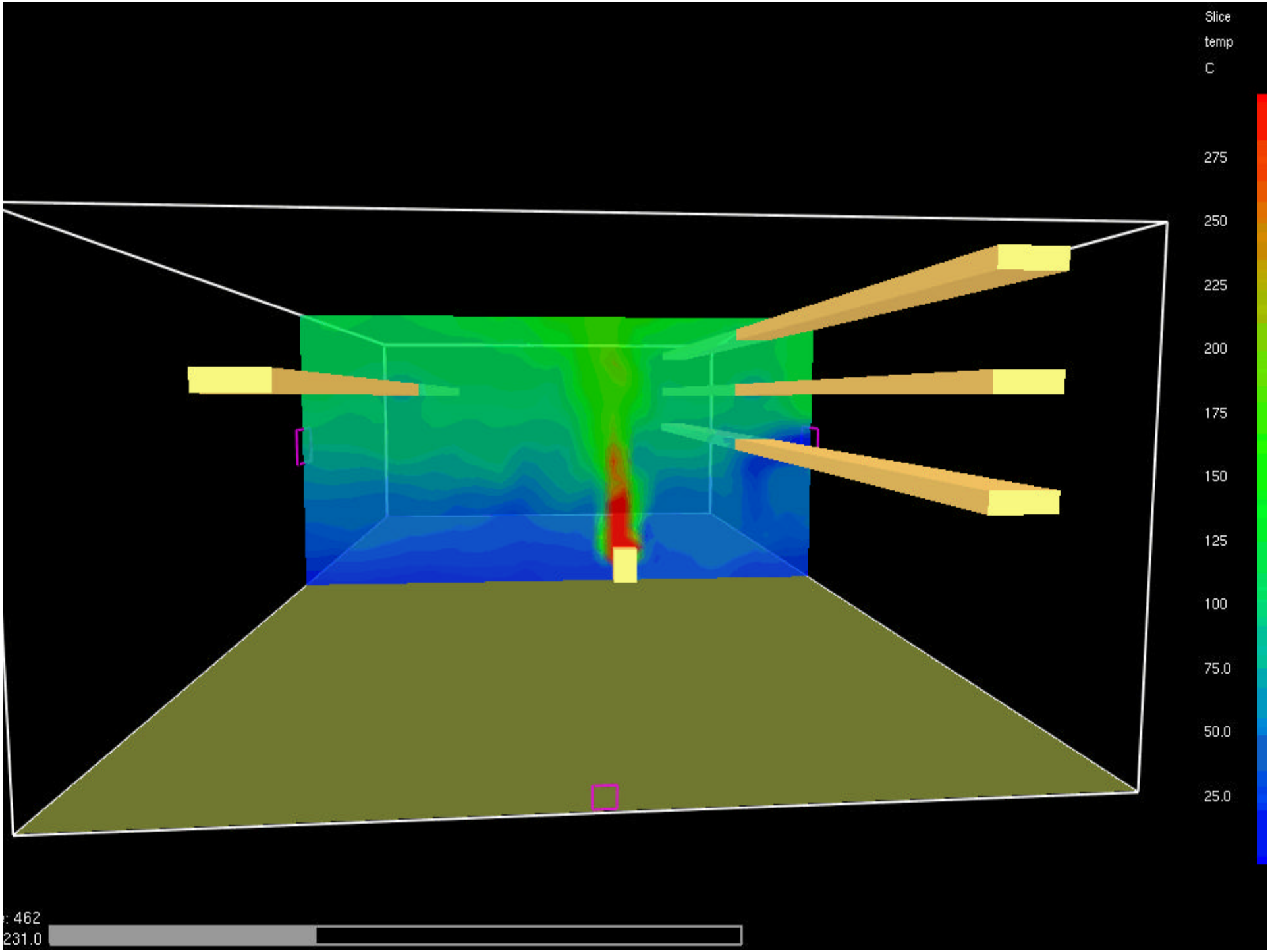
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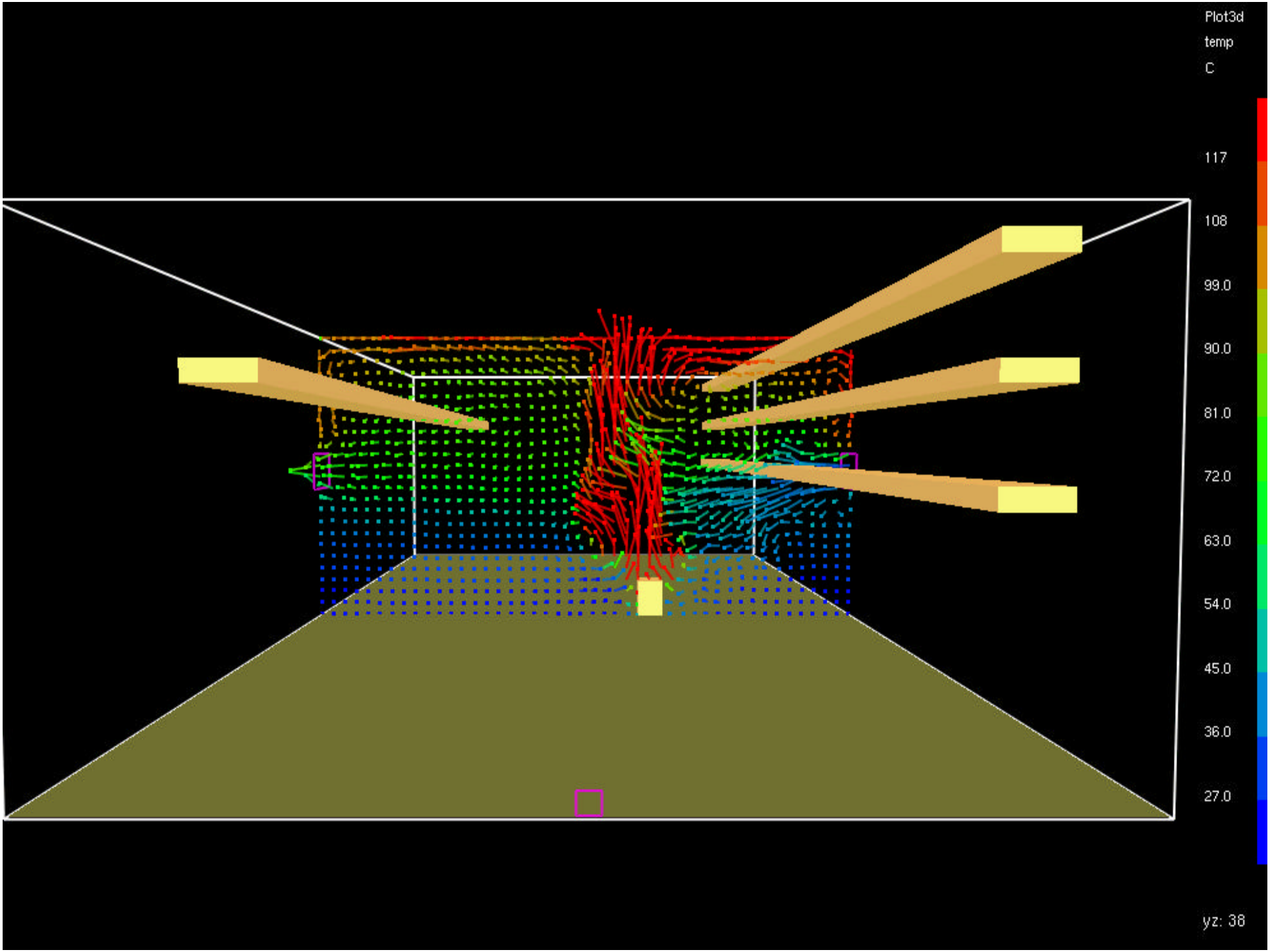
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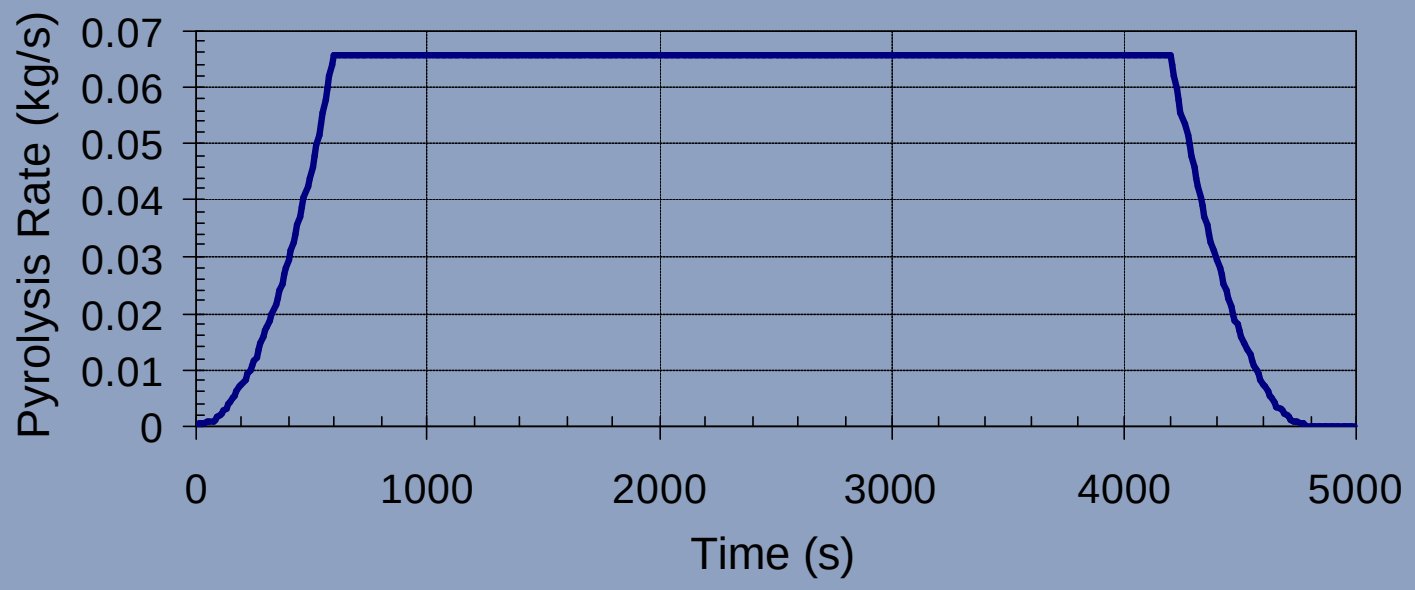
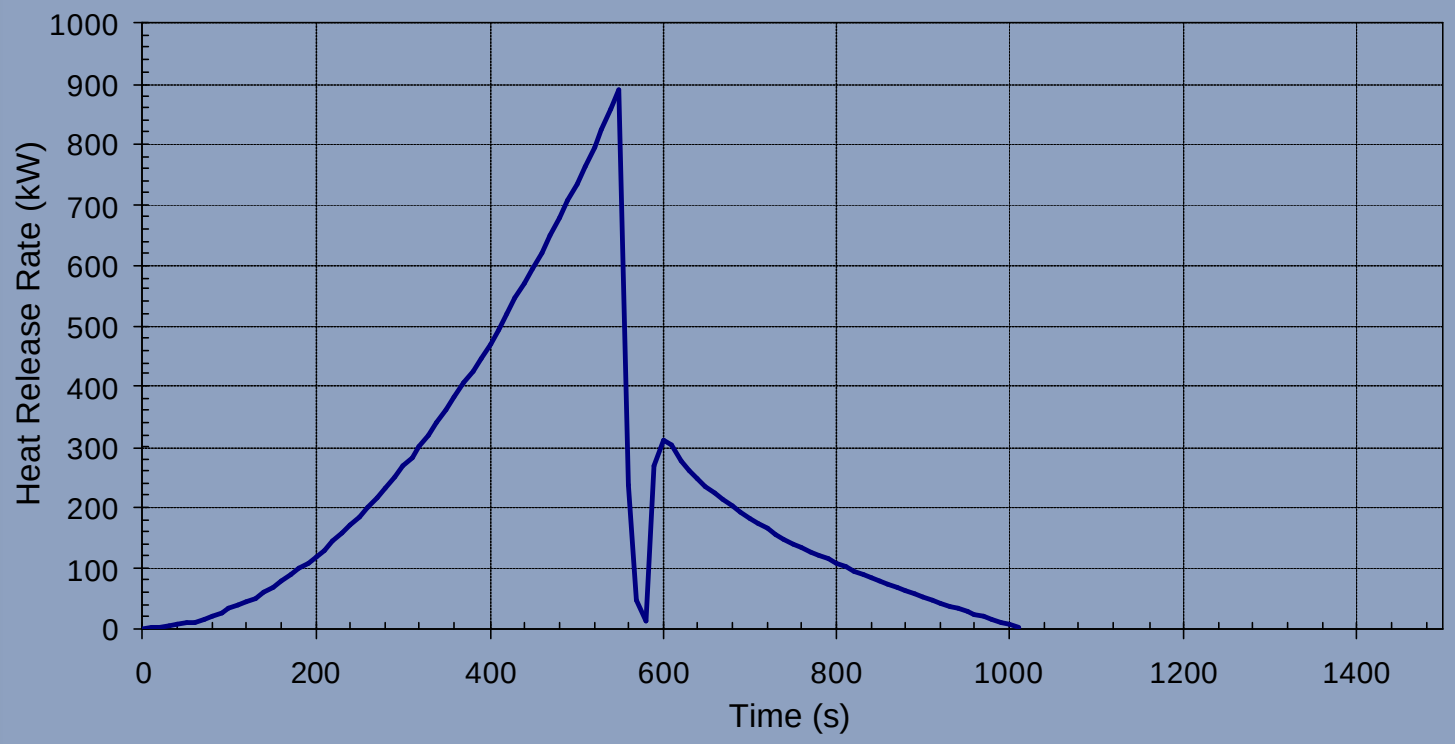
Benchmark Exercise - Part II

	Door	Vent. Sys.	Elev. Of Fire Source
Base Case	Closed	Off	3.4 m
Special Case	Open	Off	1.8 m

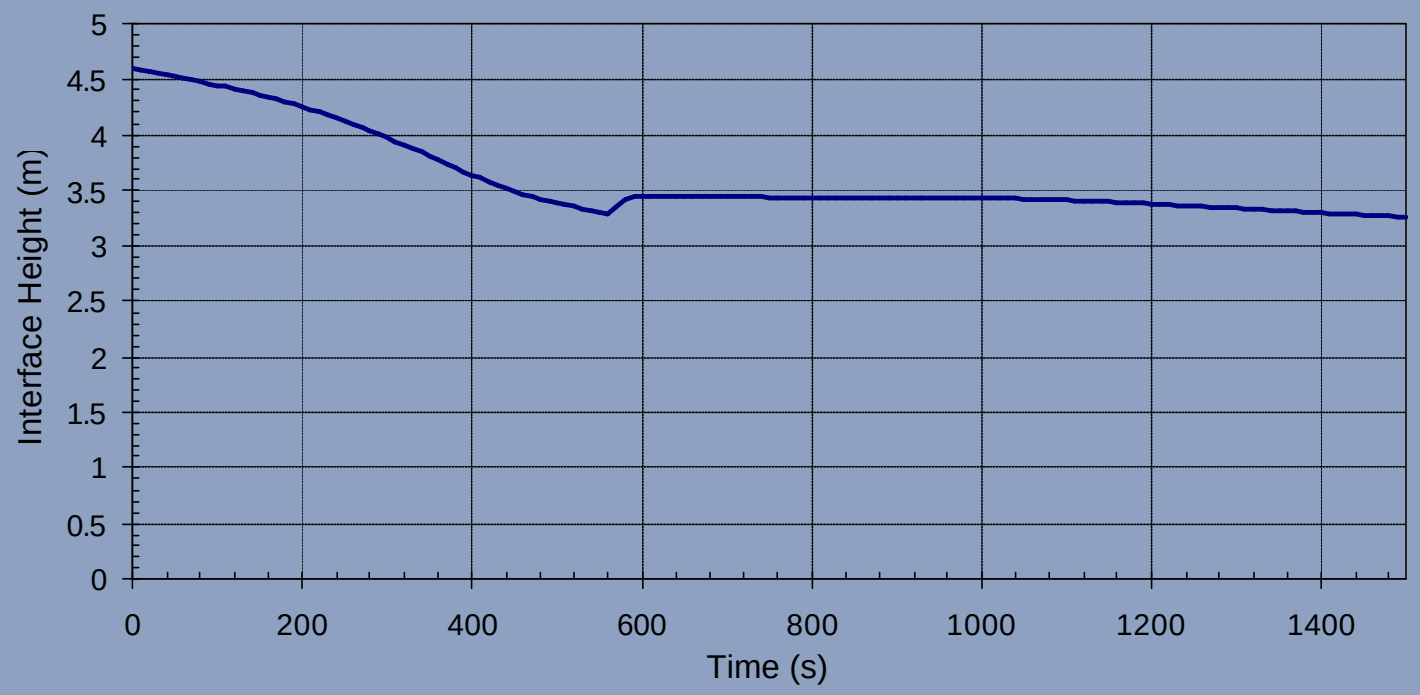
Pyrolysis Rate Part II



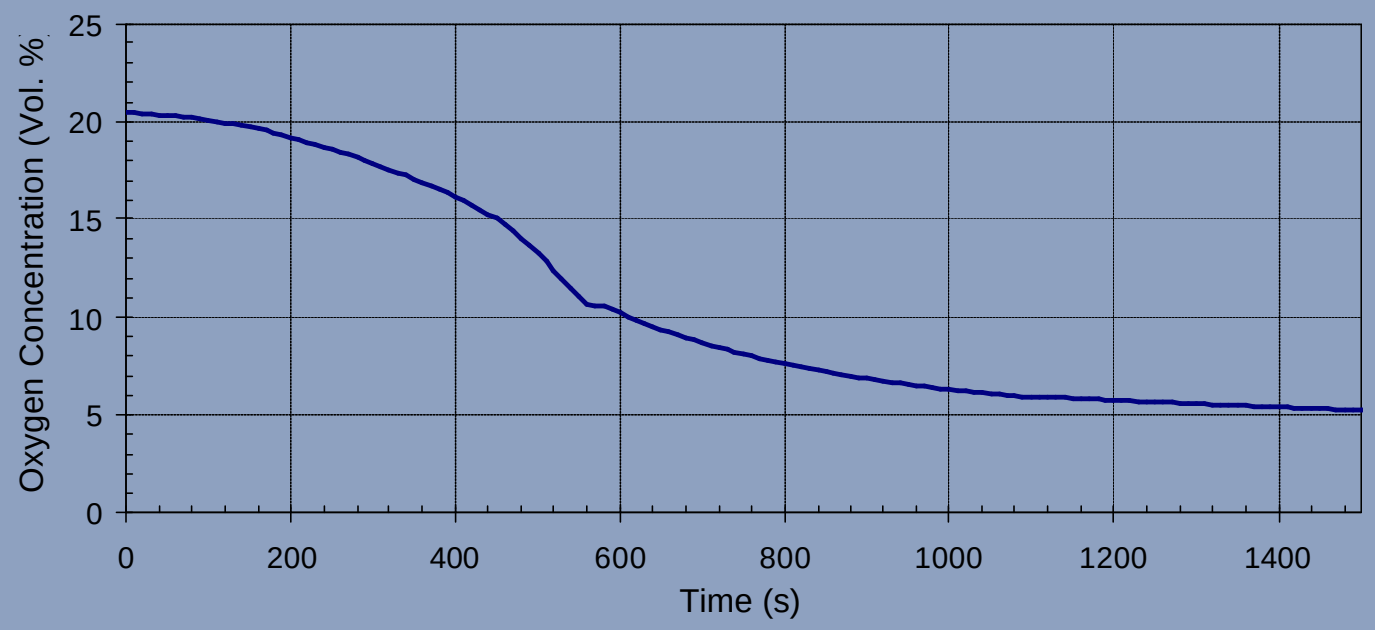
Heat Release Rate Part II



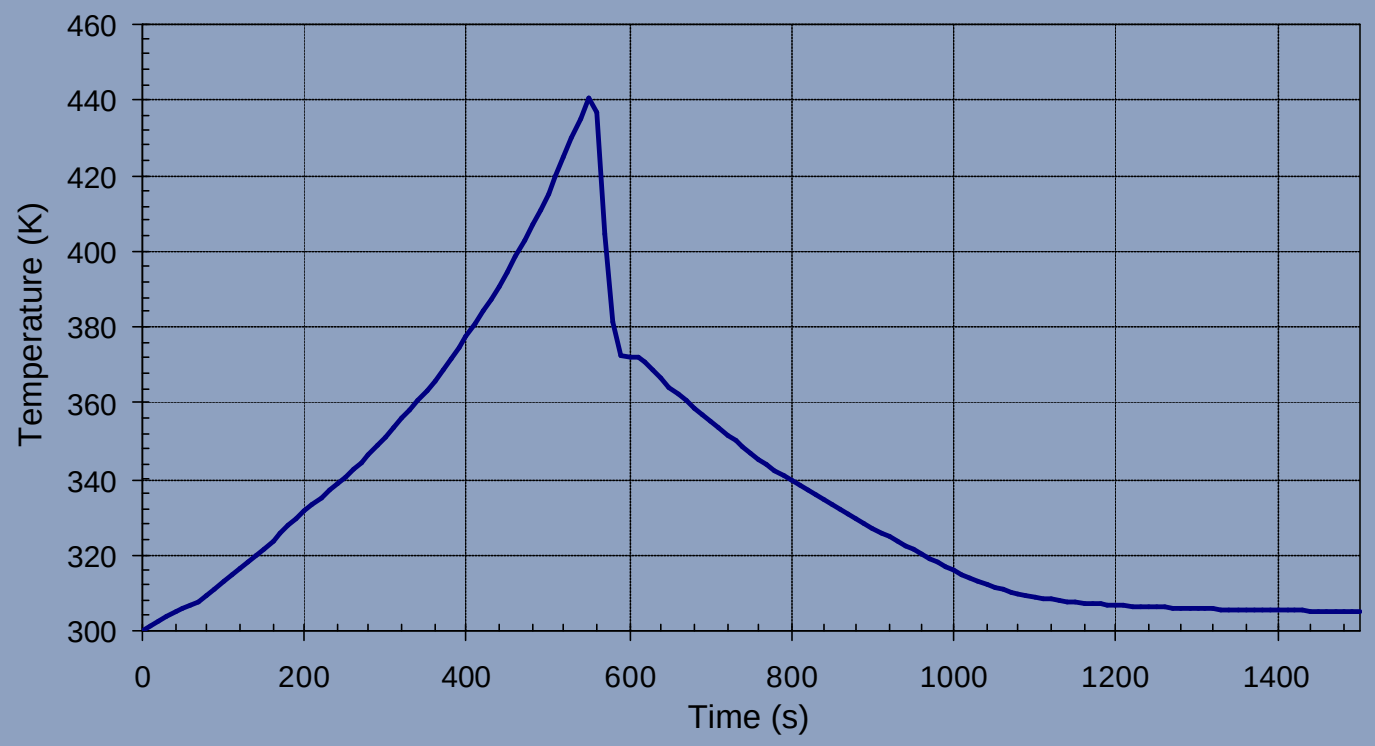
Hot Gas Layer Development Part II, Base Case



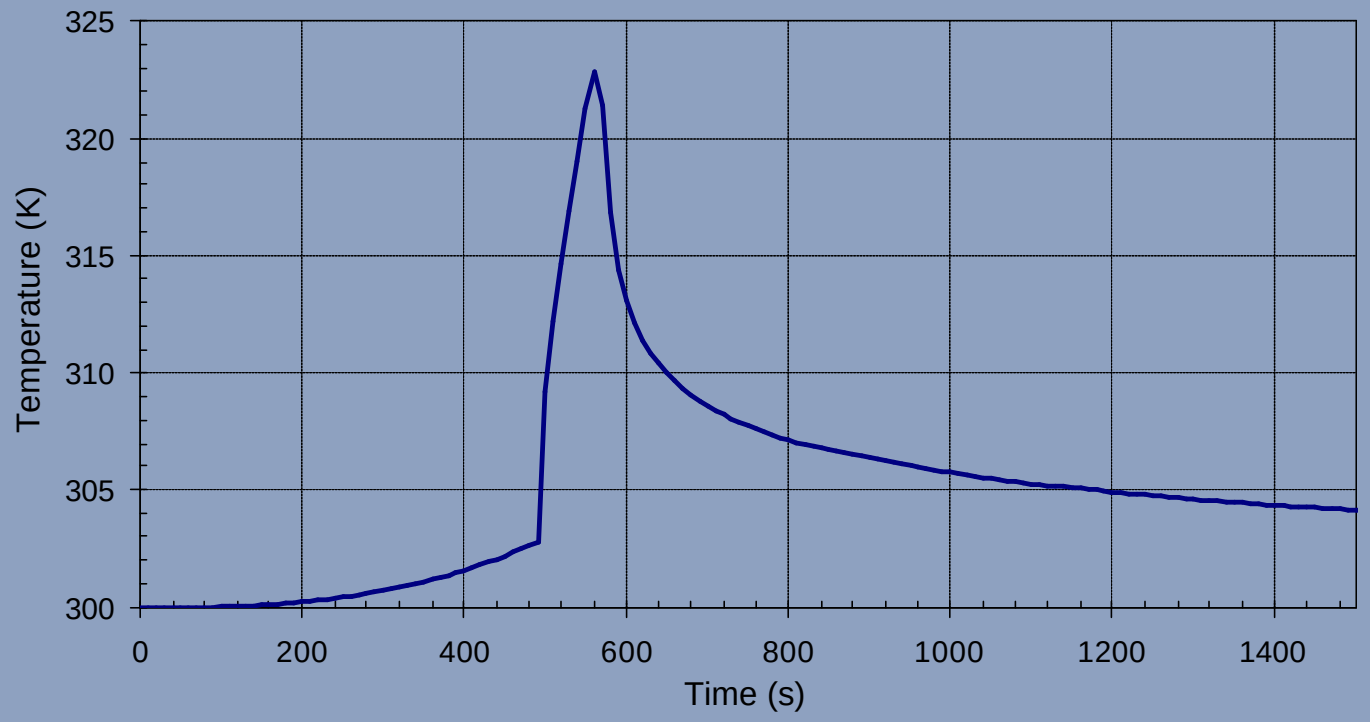
Oxygen Concentration Part II, Base Case



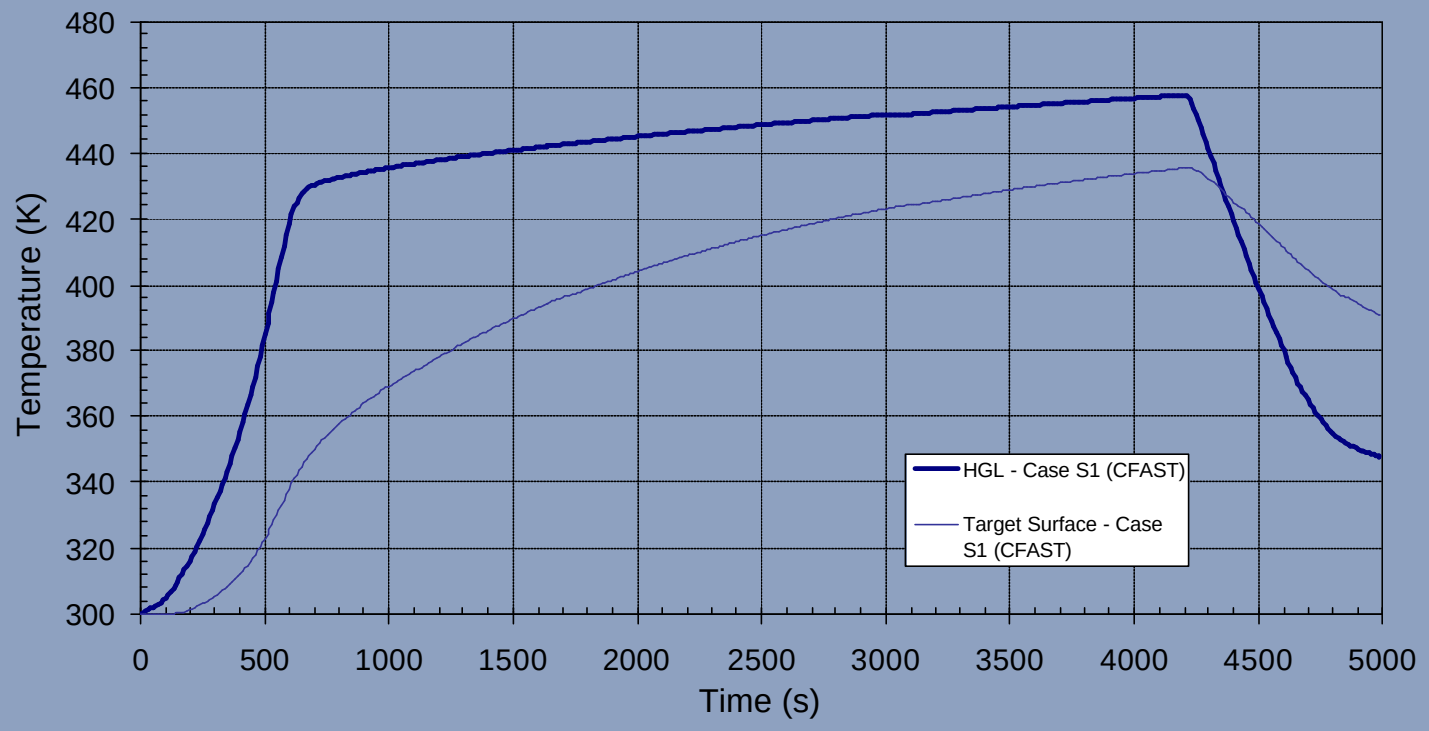
Hot Gas Layer Temperature Part II, Base Case



Target Temperature Part II, Base Case



Temperature Development Special Case



Preliminary Comparison of CFAST and FDS Results

- **Time scales for hot gas layer development and peak temperatures are similar**
- **Magnitude and timing of pressure peaks are similar**
- **Flow patterns through vents are similar**
- **Target exposed to higher temperature in FDS due to temperature gradient in hot gas**
- **Target surface temperatures deviates < 20 %**

Validation of Codes

- **CFAST validated for broad spectrum of fire scenarios in buildings**
- **Evaluation of validation of CFAST and FDS for NPP fire scenarios underway**
- **Specific validation of CFAST and FDS for target damage scenarios may be useful for better estimating uncertainties**

Strengths and Capabilities

- **CFAST provides comprehensive treatment of most physical phenomena in scenarios examined**
- **Analyses of scenarios indicate trends predicted by the sub-models are accurate**
- **Results provide significant insights beneficial for NPP fire safety engineering**

Limitations and Weaknesses

- **Conservative assumptions necessary due to limitations in modeling fire source and target heating**
- **Treatment of O_2 depletion effects on elevated fire sources is an over approximation**
- **Examination of local effects limited, e.g. mechanical ventilation**

Use of Advanced Models

- **CFD codes can be used to benchmark zone models for key issues/scenarios:**
  - **Plume flow**
  - **Elevated fire sources affected by O_2 depletion**
  - **Importance of local effects, e.g. from mechanical ventilation**

Future Efforts

- **Benchmarking exercises**
  - **Large compartments (e.g., turbine building)**
  - **Multi-compartment (horizontal and vertical flow**
  - **Control room (unique issues)**
- **International blind validation exercises**