Flammability Modeling

Use in Research, Testing and Regulation Development

International Aircraft Materials & Fire Test Working Group

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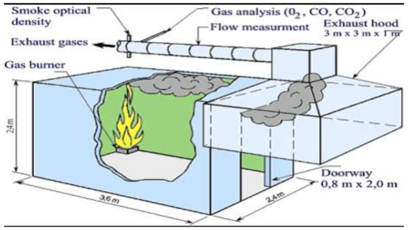
Agenda:

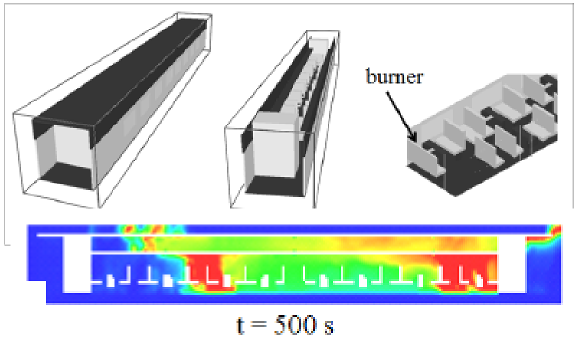
- Modeling use in the transportation and building industry
- FAA development of a new Regulation Test Method
- FAATC Ducting Test Method Development
- Boeing CFD Duct Model Development
- Future Use and Application of Modeling

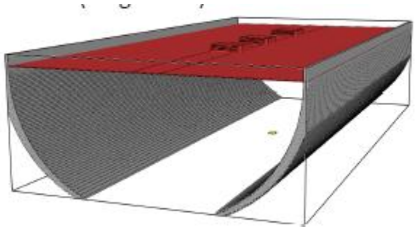
Flammability Modeling



Fire Modeling using FDS (Fire Dynamic Simulator)

1. Building Sector: Room Corner Test, Steiner Tunnel Test, SBI
2. Rail and Naval Industry: Compartment Fire Test
3. Aviation: Cargo fire containment, Smoke Transport
4. Tunnel Fires
5. Urban/Wild Fire Modeling





FAA Development of Flammability Regulations & Test Methods

BCA Engineering
Flammability Engineering

I. Cabin Safety Improvement Requirement Identified

- Accidents
- Incidents
- State-of-art

II. Identification of Targeted Commodities, Criteria/Boundaries, and Available Materials.

- Involves considerable discussion and preliminary testing to define a project approach

III. Material and Panel Characterization

- Bunsen Burner
- Foam Block
- Radiant Panel
- OSU
- MCC

IV. Intermediate/Full Scale Testing

Actual Airplane Level Performance

- Test of actual cabin configurations ensures appropriate levels of fire safety improvement can be realized

V. Correlate Data, Refine Criteria, Establish Preliminary Test Requirements

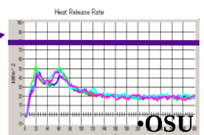
- Involves considerable discussion and analysis, and may result in further testing to define detailed test requirements

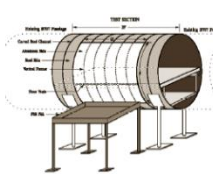
VI. Set Requirements

Lab Scale Test Requirements Defined

- Requirement determined to ensure improvement in fire safety.

- 65/65?
- 100/100?
- NPRM?





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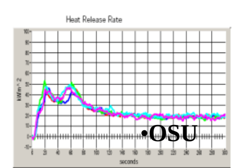


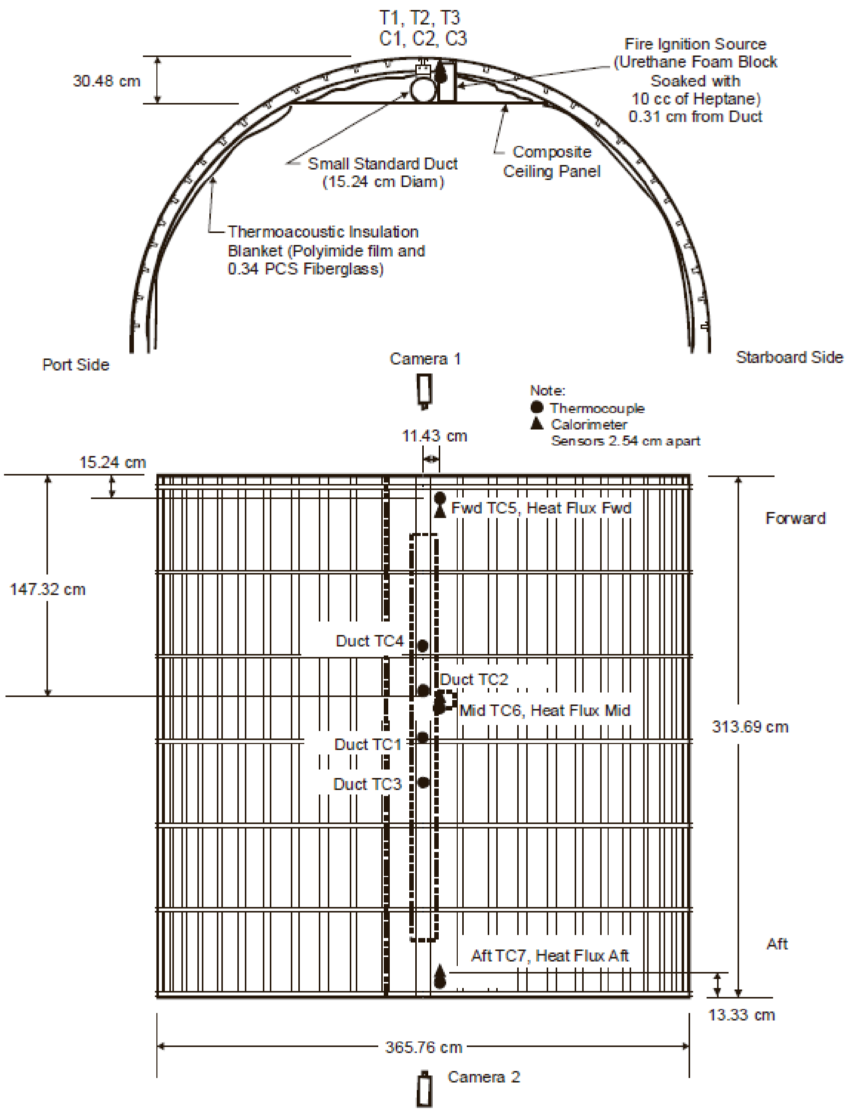
Modeling

FAATC Duct Research:

Goal: Develop a more stringent test method to assess flame propagation of ducting to replace the current 12-second vertical Bunsen burner test method.

- Full scale fuselage ducting configurations evaluated using foam block
- Materials evaluated using several bench scale test methods
  - Bunsen burner,
  - MCC
  - OSU heat release apparatus
  - Radiant panel
- Radiant panel test parameters and requirements adjusted to correlate with the full scale test results.
- Results published in 2008 (DOT/FAA/AR-08/4) and proposed a new radiant panel test method to replace the 12-second Bunsen burner test [14CFR25.853(a)].

Flammability Modeling



Full Scale Crown Test Fixture

FAATC Duct Research:

Observations:

- During the FAA research, it was observed that other factors were likely affecting the flammability performance of air ducting.
- Questions arose regarding whether there was adequate correlation of results between the full scale crown test and the radiant panel test results.
- Many of the questions focused on whether the specific crown test configuration had applicability to a wide range of duct installations.
- The tested duct samples varied in shape, diameter, length, wall thickness/mass, and materials/construction.
- The crown volume selected for most of the testing represented a small space above ceiling panels.
- Test results indicated that small differences in duct size/crown volume ratio may have a significant impact on the fire dynamics, resulting in accurate correlation to the new proposed radiant panel test method.

CFD Model Development:

Goal: Gain better understanding of complex fire dynamics that to understand the role of materials and design configurations critical to establishing clear performance criteria. Ultimately the modeling results will help validate the robustness of a new test method and performance criteria.

- The full scale ceiling crown section fabricated by the FAA was modeled using Fire Dynamics Simulator (FDS).
- Model was used to assess different duct and ceiling height configurations.
- Results were compared with experimental results to determine the effect and sensitivity of duct size and ceiling height on temperature distribution and flame propagation performance.
- Modeling results will help validate the robustness of a new test method and performance criteria.

Flammability Modeling

CFD Model Development:

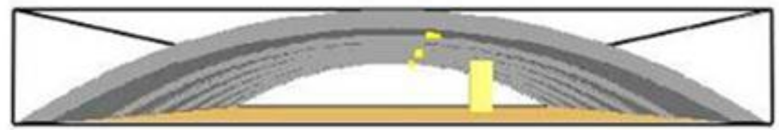
What parameters are needed to develop the Model?

1) Dimensions (crown, duct, installation locations)

2) Fuselage insulation thermal properties

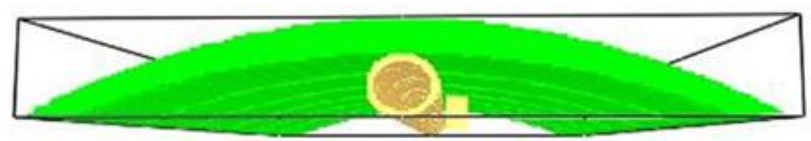
3) Fuel load / heat release rates of ignition source (foam block/heptane)

4) Duct material properties (specific heat, thermal conductivity, ignition temperatures, heat release capacity)



FAA Crown Volume without Duct

FAA Configuration #1: 6” Round Duct

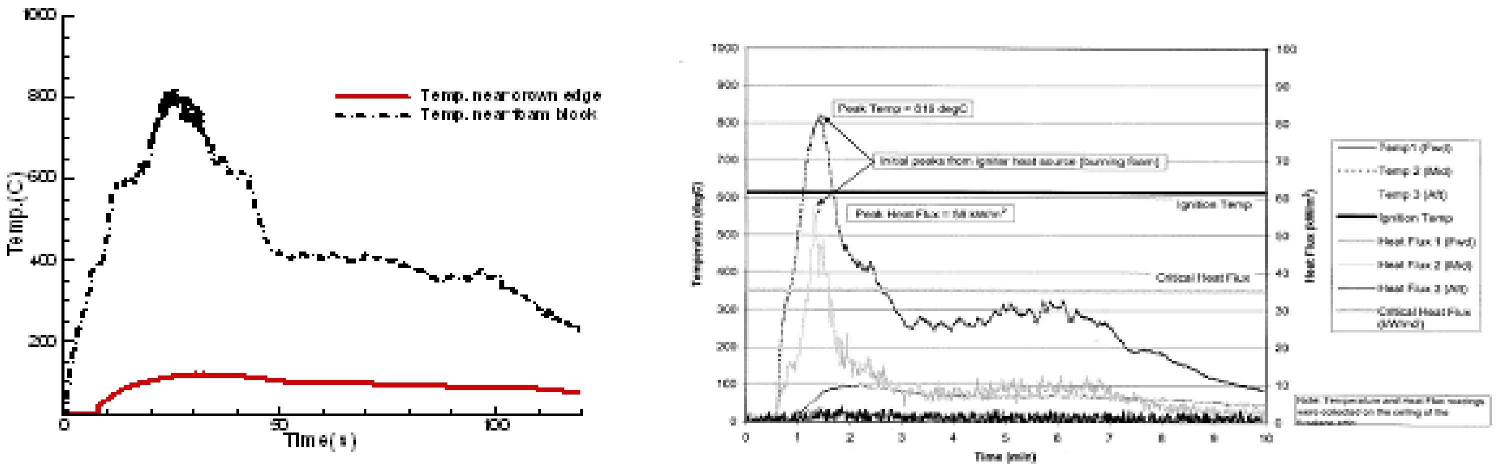


FAA Configuration #2: 8” Round Duct

FAA Configuration #3: 20” Oval duct

CFD Model Development:

Test Case #1: 6” ECS Duct



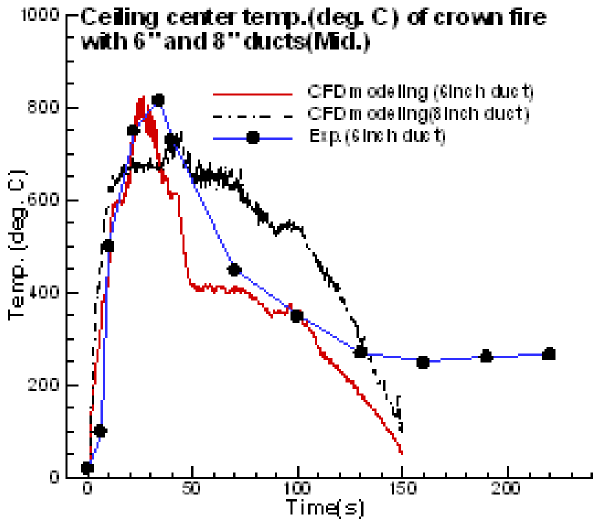
(a) Temperature at ceiling mid and fwd points (b) Experimental data [4]

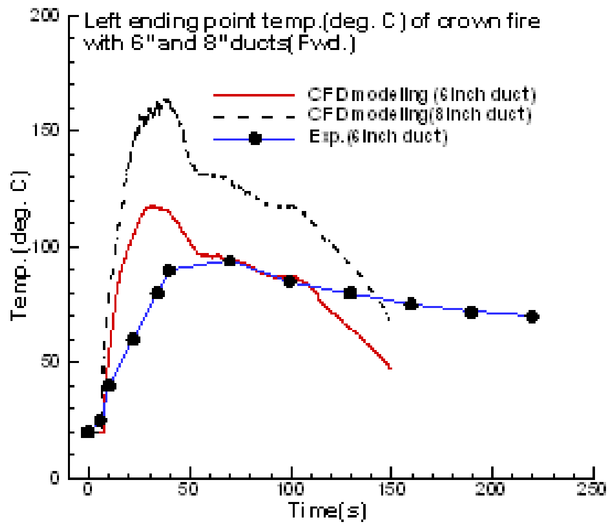
Figure 13, CAES 2: CFD results and experimental data of the narrow-body fuselage crown fire with a 6-inch ECS duct

OBSERVATION:
Peak temperatures predicted at ceiling, mid, and forward points have good agreement with the experimental data

CFD Model Development:

Test Case #2: Temperature Comparison of with 6” and 8” Duct





OBSERVATIONS:
•8” configuration shown to have higher temperature and heat flux during the fire event.

•Ceiling temperature of 8-inch ECS duct case remains higher during the test, which is an indication that different size ducts could cause higher crown temperatures.

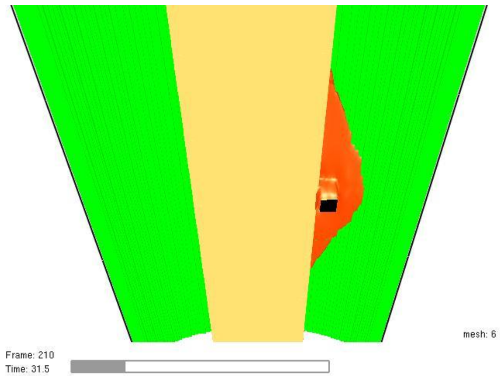
Flammability Modeling

CFD Model Development:

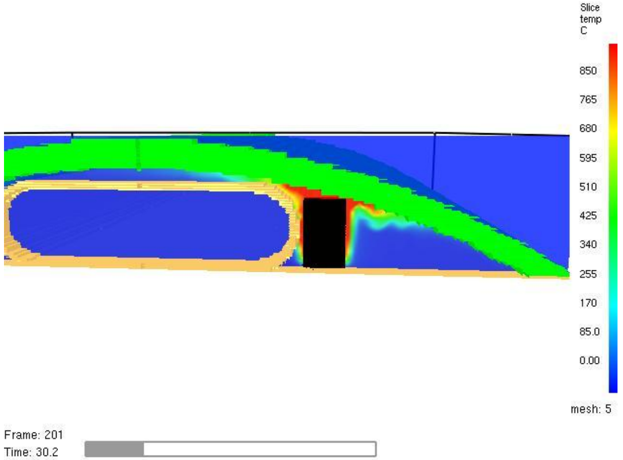
Test Case #3: 20” Oval Duct in different crown volumes (polyurethane foam core)

Crown Volume 1

Crown Volume 2



Temperature iso-surface (120C) distributions on duct and ceiling at 31 seconds.

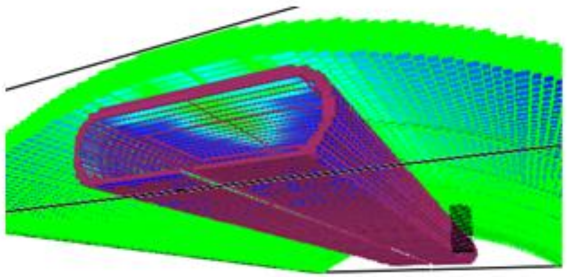


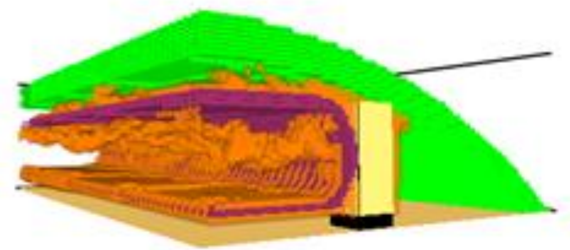
Temperature distributions at cross section (30 seconds).

Flammability Modeling

CFD Model Development:

Test Case #3: 20” Oval Duct in different crown volumes





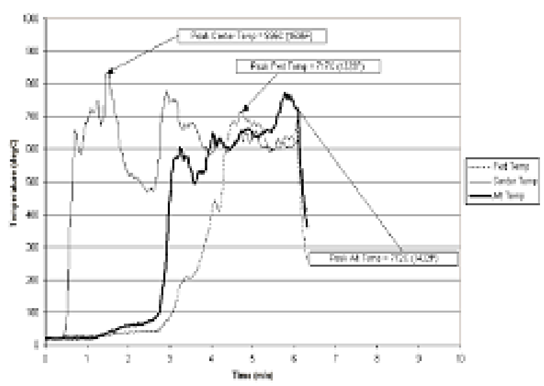
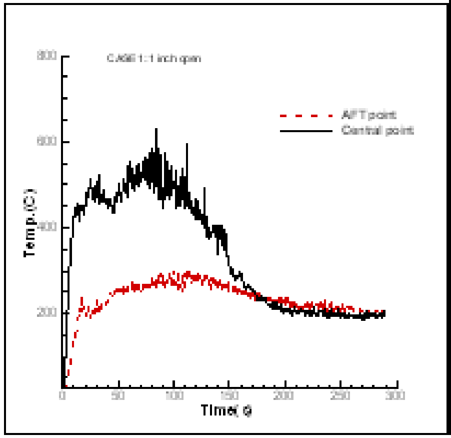
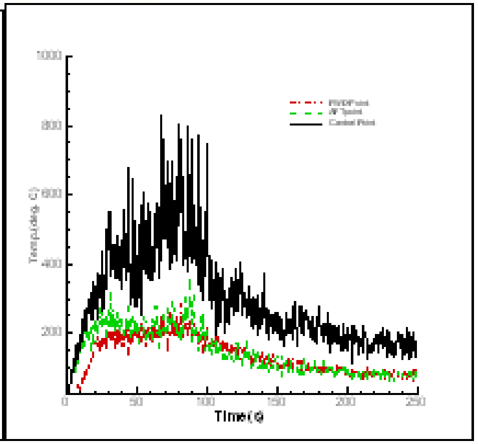


FIGURE 11. INTERMEDIATE-SCALE TEST TEMPERATURE HISTORY





FAA Experimental Data

CFD Model

CFD Model

Comparison of air temperature

CFD Model Development:

Test Case #3: 20" Oval Duct in different crown volumes

OBSERVATIONS:

•Predicted peak temperatures at the ceiling mid points are lower than the FAA experimental test data.

•Forward and aft ceiling temperatures of the two cases have are different from the experimental test data.

•Flame penetration and propagation inside the duct is not modeled in the analysis and plays an important role on the performance characteristics of this specific duct configuration.

•It's recognized that the 20-inch duct must be considered as part of combustion load for the CFD model to adequately predict actual performance.

Future Use and Application of Modeling:

1) Assessment /validation of experimental test results:
   a. Identify critical test parameters and variables
   b. Improve assessment of correlation of large scale testing and lab scale test methods
   c. Select and validate new test method pass-fail criteria

2) Performance assessment of design configurations:
   a. Design/Installation performance evaluation
   b. Safety assessments

3) Certification – “Flammability Analysis”
   a. Develop framework for future regulations to allow “Flammability Analysis”
   b. Guidance and identification of approved tools

Thank you