Analysis of Benchmark Exercise Two: An Examination of Large Turbine Hall Fires with the CFAST Fire Modeling Code

Westinghouse Safety Management Solutions LLC

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The Savannah River Site (SRS) has an obligation to fulfill Department of Energy (DOE) expectations[1, 2]. The DOE expectation is that software quality assurance (SQA) is in place that will ensure that computer software will perform its intended functions in a consistent manner and that software modifications will not result in unanticipated problems. SRS is in the process of improving the site SQA program.

The SQA program is currently being applied to CFAST, Version 3.1.6. In the process, code capabilities and limitations are being evaluated. A typical problem requiring analysis at SRS is evaluating heat transfer to a liquid filled process tank and estimating evaporation from the tank. An understanding of how to accomplish this using the output available from CFAST is required. In addition, several sample problems must be established that provide input and output so that, when the code is initially installed, it can be demonstrated that the installation was successful.

As part of the SQA effort, Benchmark Exercise 1 (Part 1) was developed into a sample problem format and work is in progress on Benchmark Exercise 2 (Part 1) for use as an additional sample problem. Under this present effort, preliminary evaluation of Benchmark Exercise 2 (Part 1) has been completed for cases 1, 2 and 3. Since CFAST is limited to a rectangular geometry, the ceiling height was adjusted to 15.84 m to maintain the turbine hall volume. A lower oxygen limit of 12%, as used in Benchmark Exercise 1, a radiative fraction of 20% and a relative humidity of 50% were used. For the wall layers, the specification stated sheet metal on top of mineral wool. A three layer material with mineral wool (5 cm thick) between two layers of sheet metal (each layer 1 mm thick) was created. Pyrolysis rates and ventilation conditions are as identified in the specification for part one of Benchmark Exercise 2.

In conclusion, SRS is charged with verifying and validating the CFAST software. Demonstration of code capabilities and limitations as well as establishment of sample problems has been accomplished by exercising benchmark problems 1 and 2. In addition, a non-fire mechanical ventilation flow case has been established.

[1] Implementation Guide for use with DOE Orders 420.1 and 440.1 Fire Safety Program. G-420.1/B-0 G-440.1/E-0. September 30, 1995.

[2] Quality Assurance for Safety-Related Software at Department of Energy Defense Nuclear Facilities. DNFSB/TECH-25. January 2000.

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SRS Perspective

- SRS has an obligation to fulfill DOE expectations
- DOE Fire Safety Program

  ". . . the use of such models is predicated on their being conservative and validated."

- Defense Nuclear Facilities Safety Board

  "Given the prominent role played by computer codes in ensuring the safe operation of DOE facilities, it is imperative that a thorough and effective approach to guaranteeing their quality be implemented." [TECH-25]

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SRS Focus

- Demonstrate code capabilities
- Understand code limitations
- Establish sample problems
- Ensure consistent analytical approach
- Document V & V efforts

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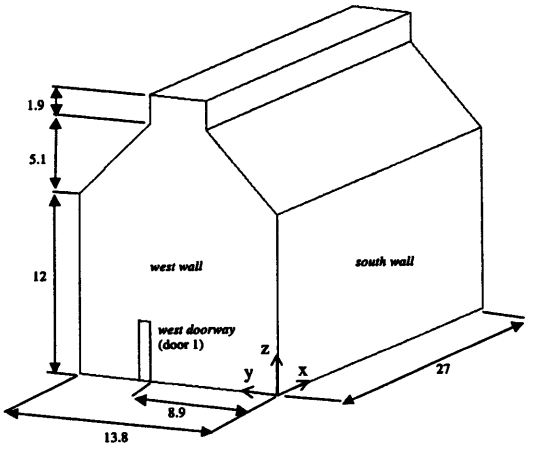
Turbine Hall Geometry



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Approach

- CFAST Version 3.1.6
- Adjusted ceiling height to maintain constant volume
- Lower Oxygen Limit - 12%
- Radiative Fraction - 20%
- Relative Humidity - 50%
- Wall Layers?

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Summary of Cases

Pyrolysis Rates for Part 1

Case 1		Case 2		Case 3	
t (min)	*dm/dt* (kg/s)	*t* (min)	*dm/dt* (kg/s)	*t* (min)	*dm/dt* (kg/s)
0.0	0.0	0.0	0.0	0.0	0.0
0.22	0.033	0.23	0.057	0.22	0.064
1.5	0.045	0.5	0.067	1.05	0.084
4.8	0.049	1.52	0.081	2.77	0.095
5.45	0.047	3.22	0.086	4.27	0.096
6.82	0.036	4.7	0.083	4.87	0.091
7.3	0.0	5.67	0.072	5.5	0.07
		6.2	0.06	5.75	0.0
		6.58	0.0		

Ventilation Conditions for Part 1

Case 1	Case 2	Case 3
doors closed no mech. exhaust natural leakage	doors closed no mech. exhaust natural leakage	doors open (0.8 m x 4m) mech. exhaust (11 m^3/s) ignore natural leakage

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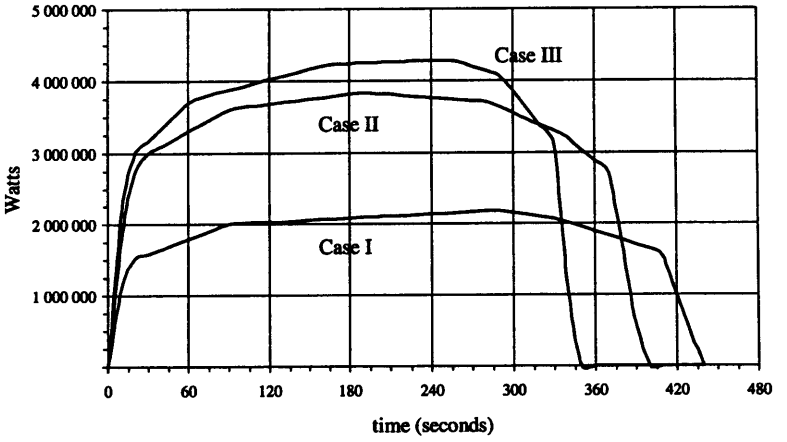
Heat Release Rate



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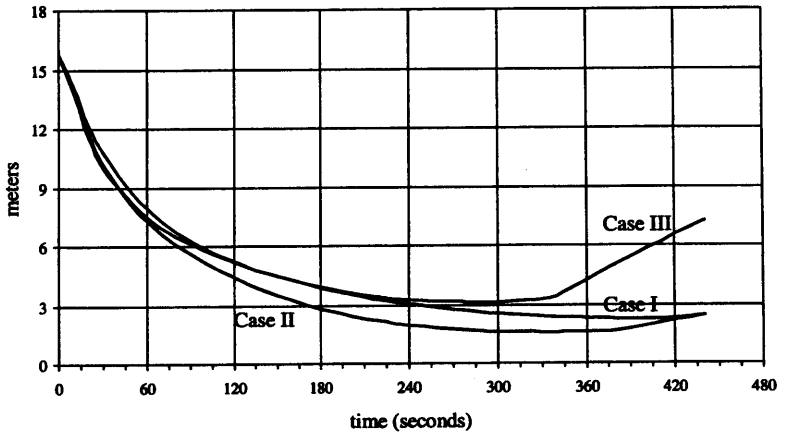
Interface Height



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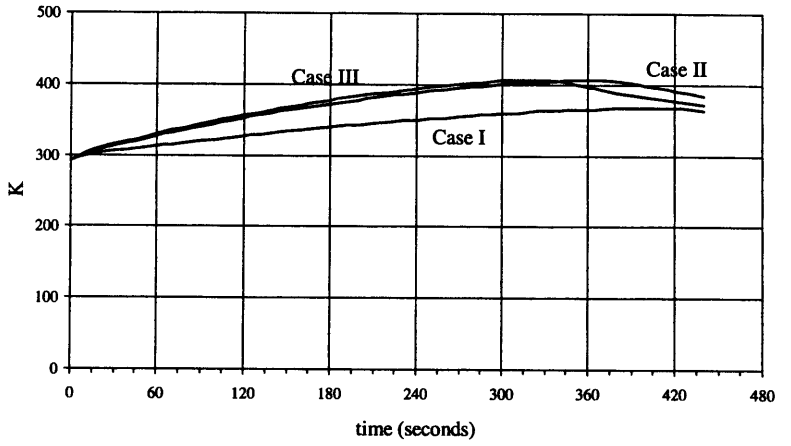
Upper Layer Temperature



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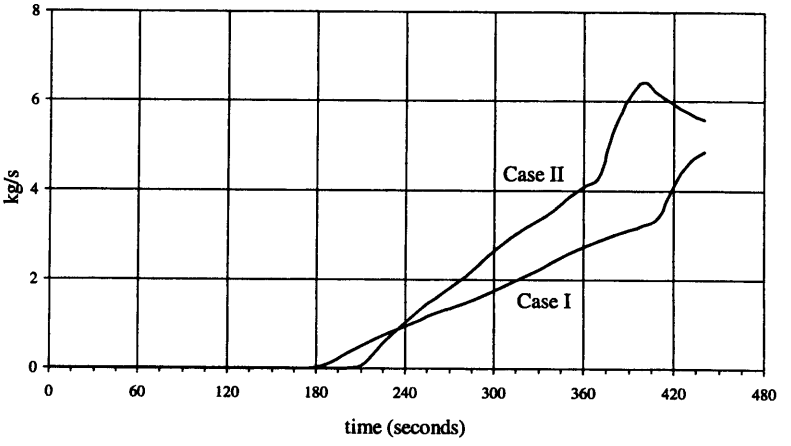
Infiltration Flow Rate (Cases I & II)



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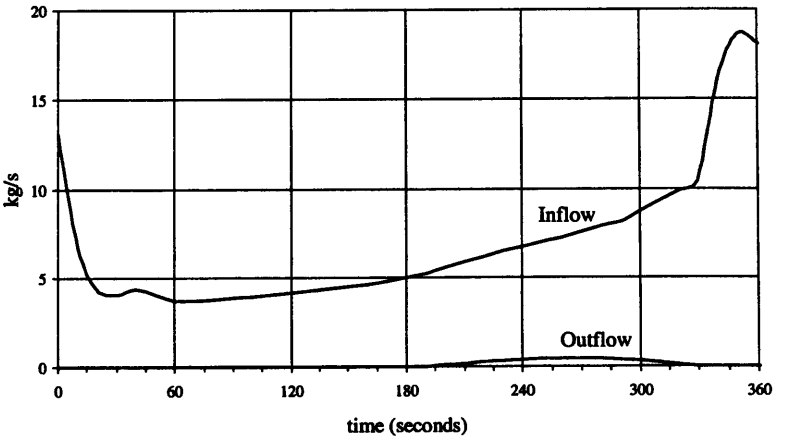
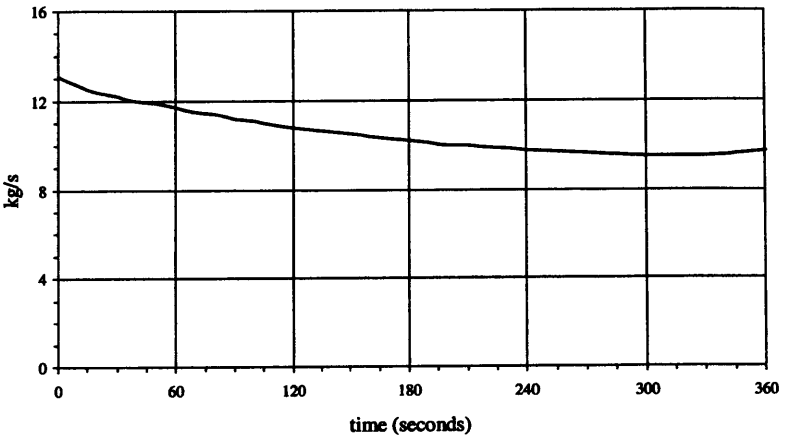
Door Flow Rate (Case III)



Mechanical Exhaust Flow Rate (Case III)



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Conclusions

- Demonstrate code capabilities
- Understand code limitations
- Establish sample problems
- Ensure consistent analytical approach
- Document V & V efforts