PSAM 14

Probabilistic Safety Assessment and Management

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Uncertainty Analysis for Input Parameters of Electrical Cabinet Fire Simulation by Coupling Latin Hypercube Sampling and CFAST

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1 Introduction

Introduction

- Fire risks in nuclear power plants

  The safety of reactor core

- Main control room

  control center; operators' lives and facilities' functions

- Fire modeling

  fire risk evaluation tool

- Parameter uncertainty for fire modeling

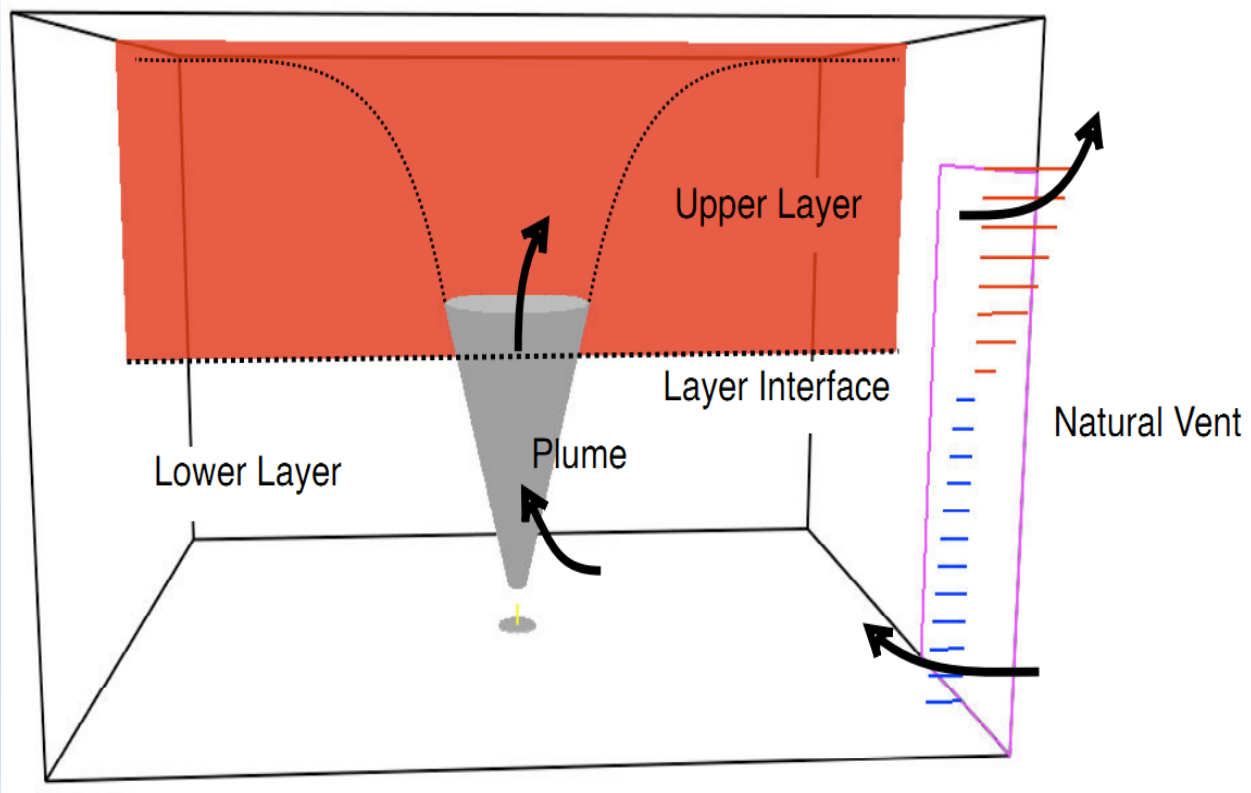
  uncertainty analysis

Objective:

Based on electrical cabinet fire scenarios in a main control room (MCR), parameter uncertainties were evaluated by coupling Latin Hypercube Sampling and CFAST

Introduction

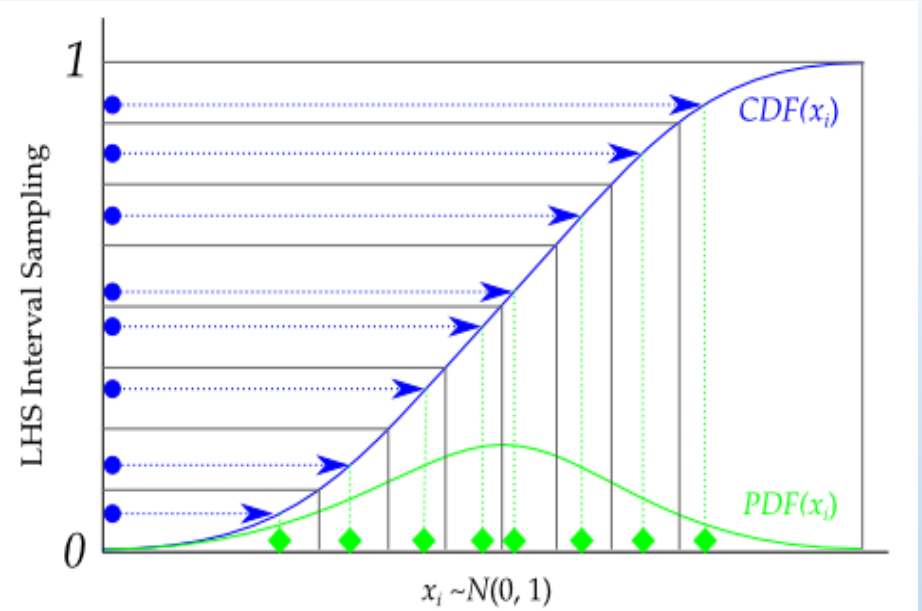
Schematic of software-CFAST



Introduction

Advantage:

Drastically reduce the number of runs necessary to achieve a reasonably accurate result



Procedure:

① split the [0,1] interval into N equiprobable intervals
② propagate via the inverse CDF to the output distribution
③ take N standard samples from each interval of the output distribution

2 Fire Modeling

Fire Modeling

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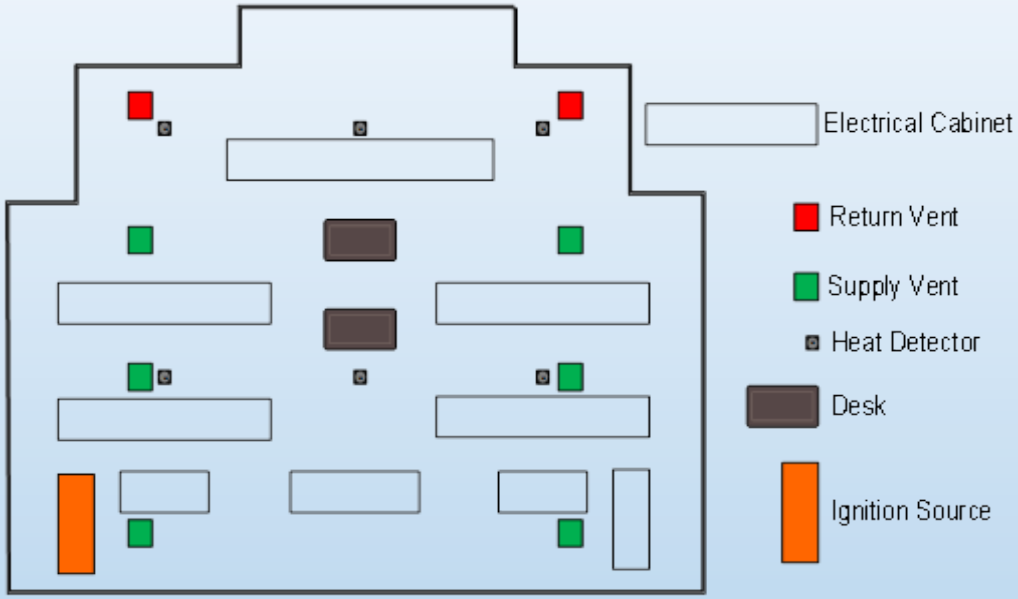
Layout:

①irregular structure
②electrical cabinets
③6 supply vents and 2 return vents
④6 heat detectors installed



Assumptions:

①door is assumed to be closed
②operators is assumed to be between two desks
③fire source is modeled 0.3 m below top surface of the ignited electrical cabinet

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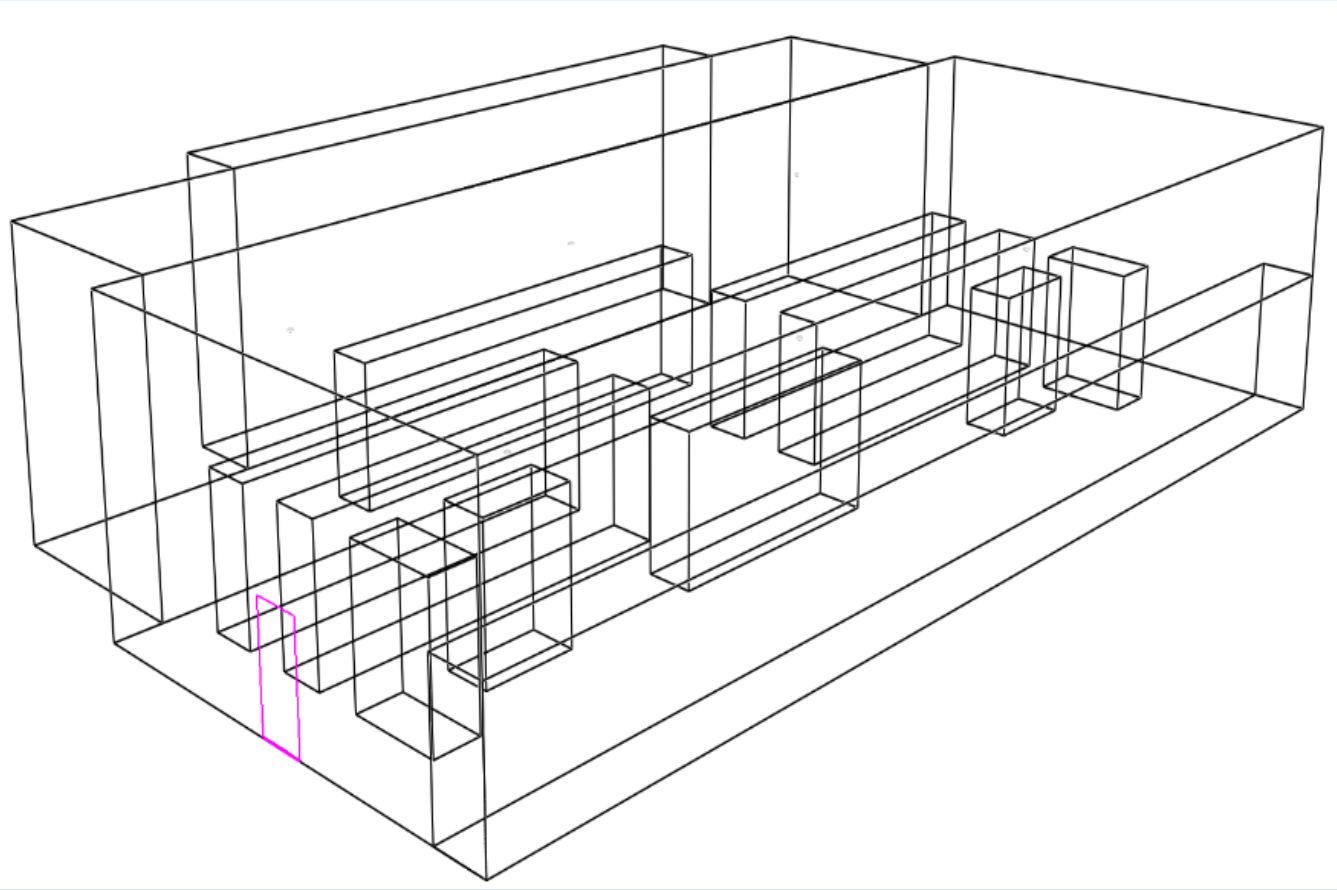

- **Heat release rate**

  Energy released per second

- **Soot yield**

  mass of soot produced per unit mass of fuel consumed

- **Activation temperature**

  temperature at which detectors activate

- **Response time index**

  feature how fast detectors response in fire scenarios

Fire Modeling

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Parameter	Distribution	Parameter1	Parameter2
Heat Release Rate[1]	Gamma	$\alpha=0.7$	$\beta=216$
Soot Yield[2]	Gamma	$\alpha=2.375$	$\beta=0.047$
Activation Temperature[3]	Normal	$\mu=80$	$\sigma=10$
Response Time Index[3]	Normal	$\mu=0.25$	$\sigma=0.03$

[1] EPRI, NRC-RES. NUREG/CR-6850 EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology [R]. U.S. Nuclear Regulatory Commission and Electric Power Research Institute, 2005.
[2] Tom Elicson, Jim Bouchard, Heather Lucek, Bentley Harwood. Calculation of Fire Severity Factors and Fire Non-Suppression Probabilities for a DOE Facility Fire PRA [C]. ANS PSA 2011 International Topical Meeting on Probabilistic Safety Assessment and Analysis. Wilmington: ANS, 2011
[3] Jia Jia. Study on Assessment Methodology of Ship Fire survivability [D]. Hefei: University of Science and Technology of China, 2014.

3 Results

Results

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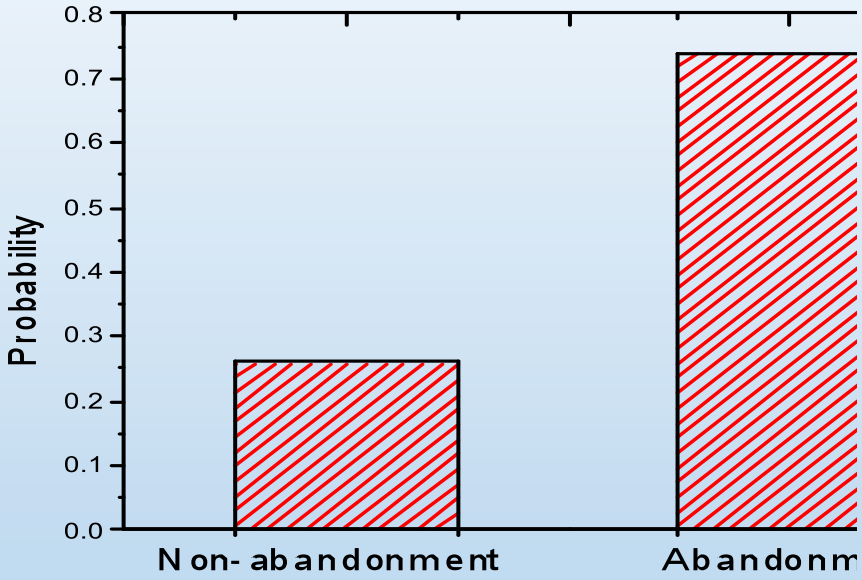

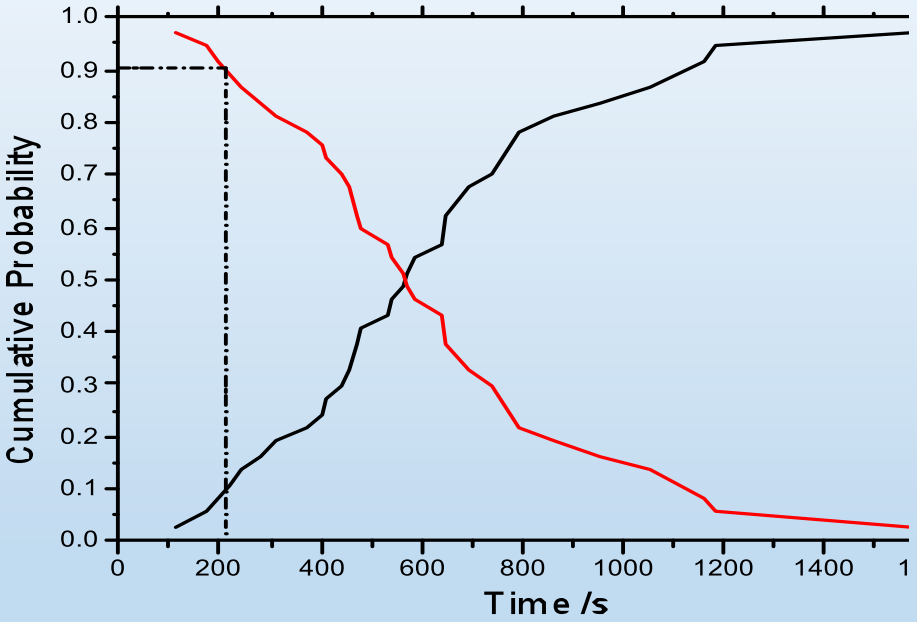

Results

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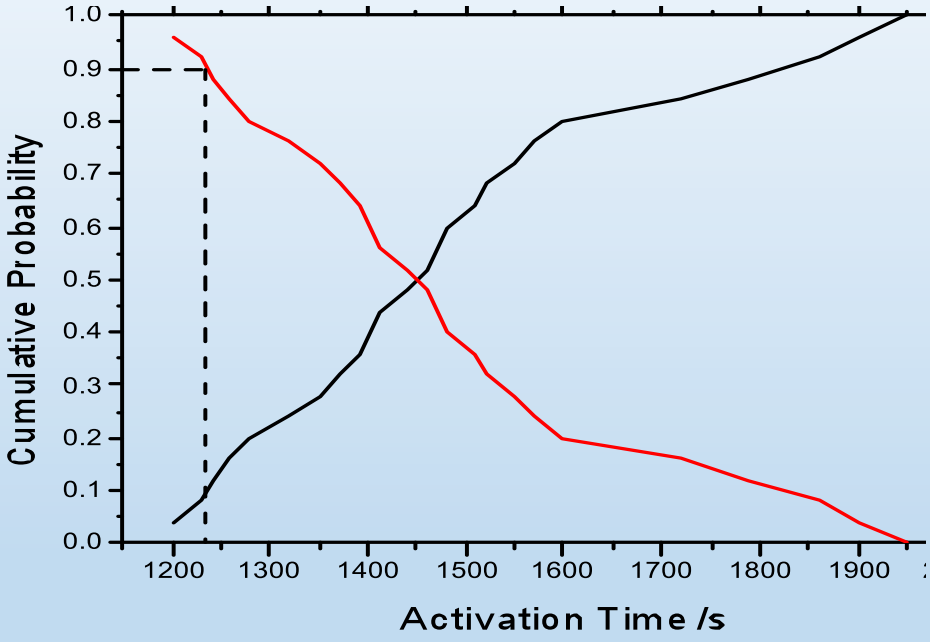
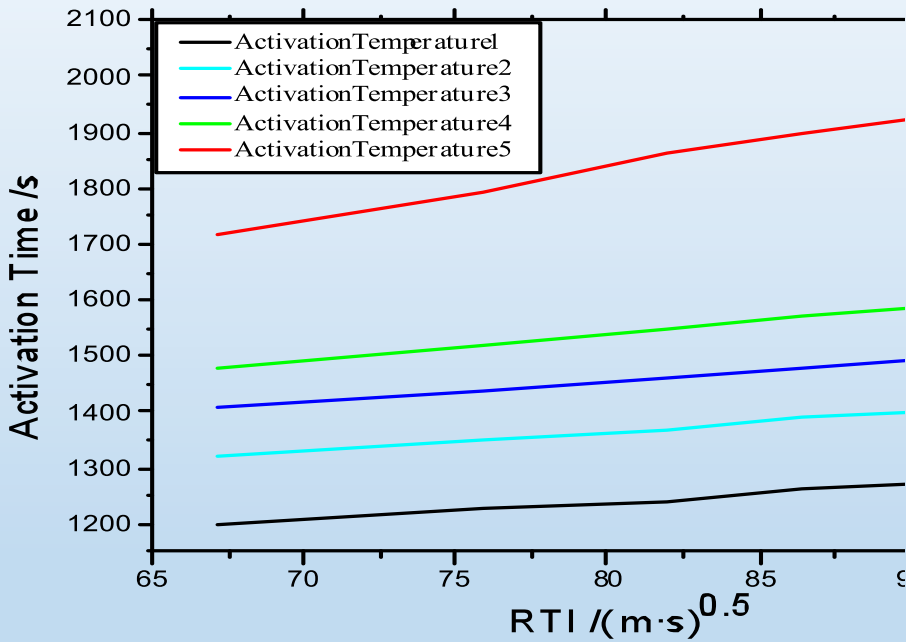


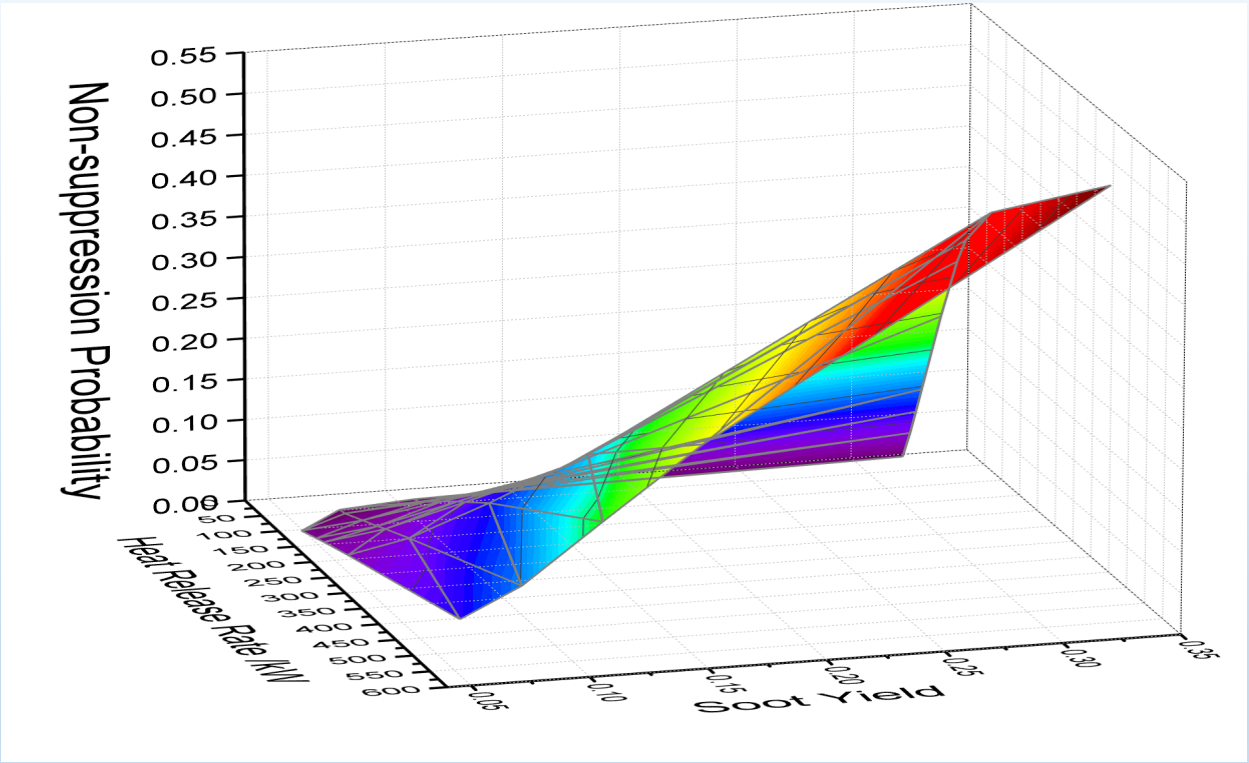


non-suppression probability is an estimate of the overall likelihood that given a fire scenario in the postulated fire ignition source, the damage to the target set will occur before the fire is finally suppressed. It can be calculated by the following equation:

$$NS(t) = e^{-\lambda t}$$

where λ is the suppression rate constant, 0.33/min for the MCR fire. t is the time from fire ignition to operators abandoning the MCR.

Results


Non-suppression Probability
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Heat Release Rate /kW
50
100
150
200
250
300
350
400
450
500
550
600
Soot Yield
0.05
0.10
0.15
0.20
0.25
0.30
0.35

4 Conclusion

Conclusion

- Heat release rate and soot yield, the most important factors for fire simulations, can lead to the MCR's inhabitability.
- Statistical results show that abandonment probability is 74% and the 0.9-quantile for complementary cumulative probability curve is around 220s.
- Activation time is heavily affected by activation temperature and response time index.
- Non-suppression probability increases with heat release rate and soot yield increasing.

THANK YOU!

Presented by Changhong PENG