Excel Fire Modeling and CFAST Integration

2015 DOE Fire Safety Workshop

May 5-7, Alexis Park Hotel

EGS INC.
Empowered Global Solutions
Solving Our Partners Staffing Challenges

Agenda

- Introduction
- Why Excel?
- Capabilities
- How It Works
- Limitations
- Looking Forward

About Me

Rob Plonski

Undergrad in Mechanical Engineering

Masters in Fire Protection Engineering

PE in NM

(2009-2015)

Fire Protection Engineer

(Current)

Fire Protection Engineer

Excel Fire Modeling (Why?)

Why do I want to use Excel?

- Fast
- Simple (equations/correlations)
- Reliable
- Easy to use
- Easy to explain
- Easy to distribute

NUREG 1805: **Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program**

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

22 separate tools (Fire Dynamics Tools)

- Predicting HGL, Flame Height, Burning Duration, etc.

Ways to Model Fire

Hand Calculations

Zone Models

Field Models

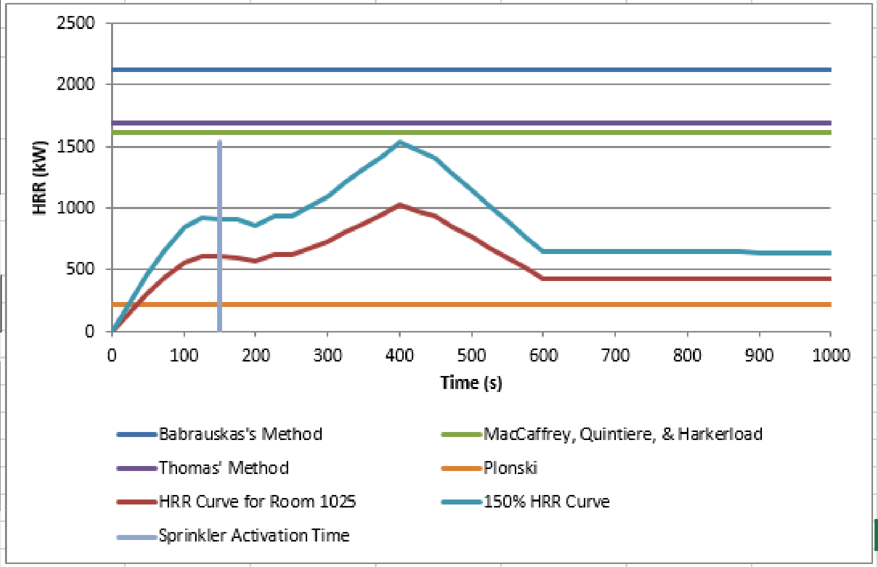
Excel Fire Modeling (The Model)

HVAC (Rm changes/Hr)	0.00		Distance to Sprinkler Head (m)	2.5
Wind Speed	0.00		Sprinkler Head RTI (SI Units)	80
Time Door Open (s)	300.00		Sprinkler Activation Temp (°C)	74
CFAST Instalaltion Location. Default is "C:\NIST\cfast511"			**Sprinkler Activation Time (s)**	150
C:\NIST\cfast511				

Object	Credible Sources	Adjustment Factor
Desk	1	1
Computer	1	1
Chair	1	1
Trashbag	1	1

Reload Database

Compute



Room Number	1025
Room Temp (°C)	20
Room Dimensions	
Length (m)	4.00
Width (m)	4.00
Height (m)	3.00
Area (m2)	80
Doorway Dimensions	
Width (m)	0.91
Height (m)	2.13
Area (m2)	1.94

Time (s)	0	25	50	75	100	125	150	175	200	225
Total HRR (kW)	**0.0**	**154.4**	**308.9**	**445.3**	**564.0**	**614.3**	**608.8**	**603.3**	**571.9**	**624.8**
Desk 1	0.0	6.3	12.5	18.8	25.0	31.3	37.5	43.8	50.0	137.5
Computer 1	0.0	4.4	8.9	13.3	17.8	22.2	26.6	31.1	35.5	43.1
Chair 1	0.0	56.3	112.5	168.8	225.0	212.8	200.7	188.5	176.3	164.2
Trashbag 1	0.0	87.5	175.0	244.5	296.3	348.0	344.0	340.0	310.0	280.0

Excel Fire Modeling (Composition)

<u>Modular Construction</u>

- HRR Database
- Cumulative HRR Development
- Flashover Correlations
- Sprinkler/Heat Detector Activation Time
- Simulation History
- Development of CFAST Input File

Excel Fire Modeling (Capabilities)

HRR Database

** Times MUST be input evenly divisible by 25 and hrr should either terminate or have a 1000s timestep										
Name	**T1**	**HRR1**	**T2**	**HRR2**	**T3**	**HRR3**	**T4**	**HRR4**	**T5**	**HRR5**
Desk	200	50	300	400	400	650	600	150	1000	300
Computer	200	35.53333	300	65.8	450	225.7	500	195.6667	600	131
Chair	100	225	250	152	500	100	1000	80		
Trashbag	50	175	75	244.5	125	348	175	340	225	280

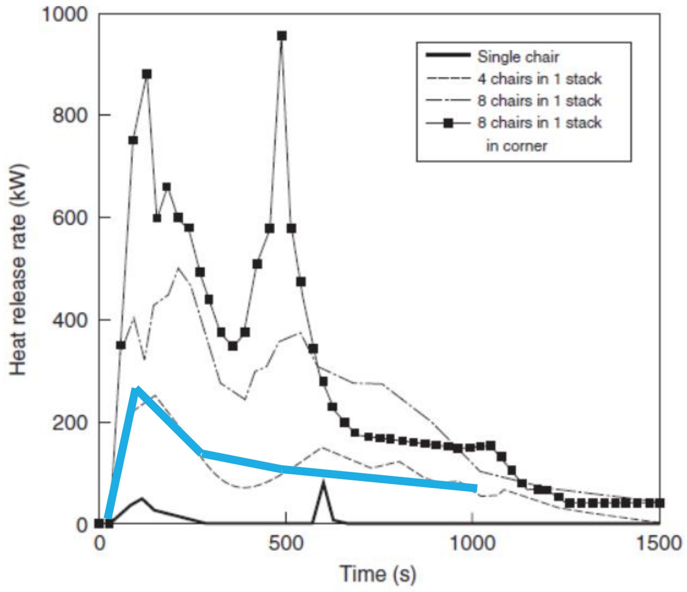


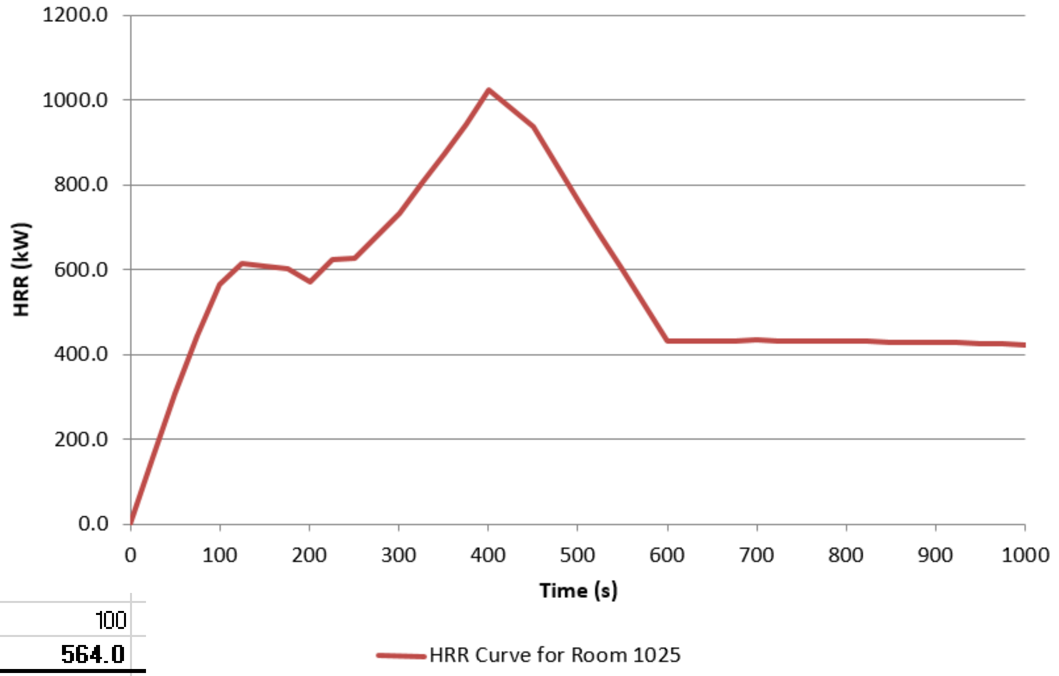
Figure 3-1.16. ***Metal-frame, upholstered stacking chairs.***

Excel Fire Modeling (Capabilities)

Cumulative HRR Development

Object	Credible Sources	Adjustment Factor
Desk	1	1
Computer	1	1
Chair	1	1
Trashbag	1	1

Compute

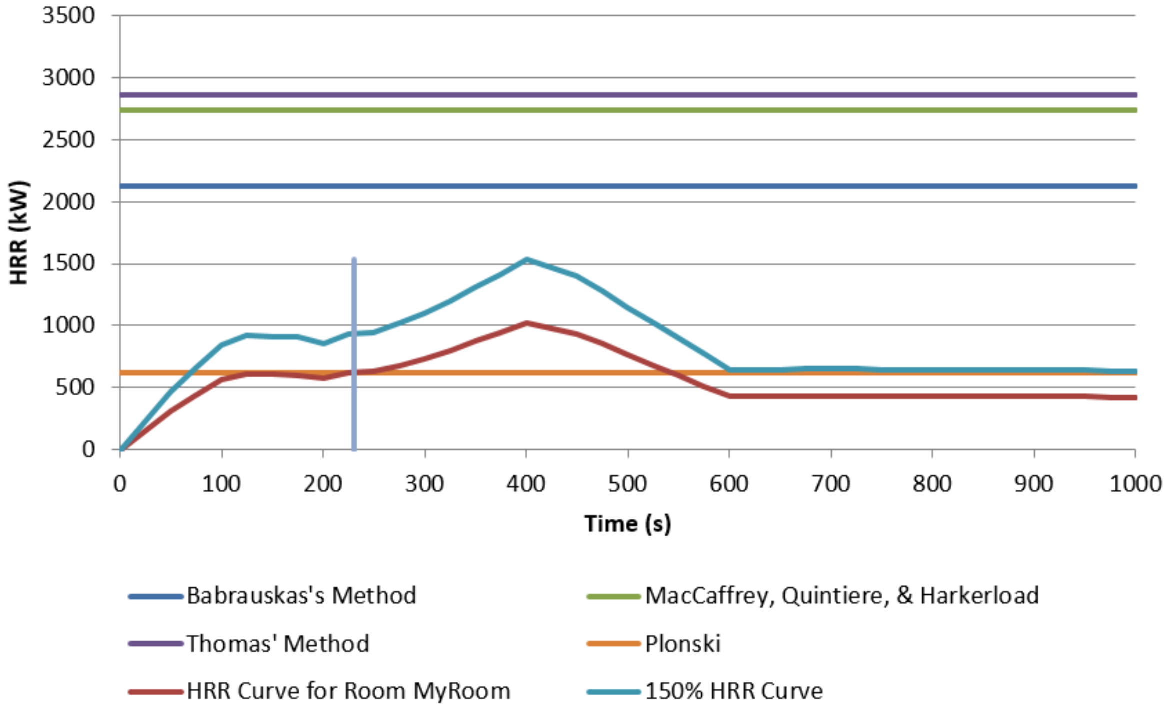


Time (s)	0	25	50	75	100
Total HRR (kW)	**0.0**	**154.4**	**308.9**	**445.3**	**564.0**
Desk 1	0.0	6.3	12.5	18.8	25.0
Computer 1	0.0	4.4	8.9	13.3	17.8
Chair 1	0.0	56.3	112.5	168.8	225.0
Trashbag 1	0.0	87.5	175.0	244.5	296.3

Excel Fire Modeling (Capabilities)

Flashover Correlations

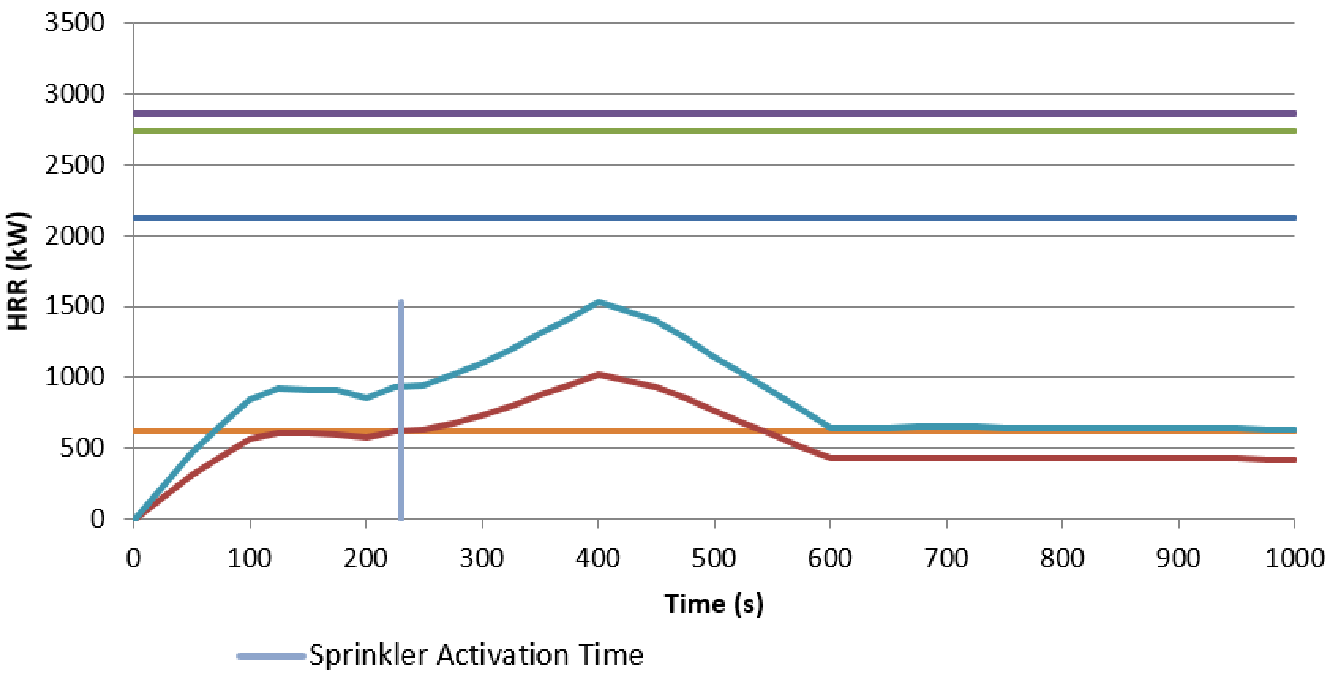
Min HRR for Flashover		
Babrauskas's Method	MacCaffrey, Quintiere, & Harkerload	Thomas' Method
2122 kW	2740 kW	2864 kW



Excel Fire Modeling (Capabilities)

Sprinkler/Heat Detector Activation Time

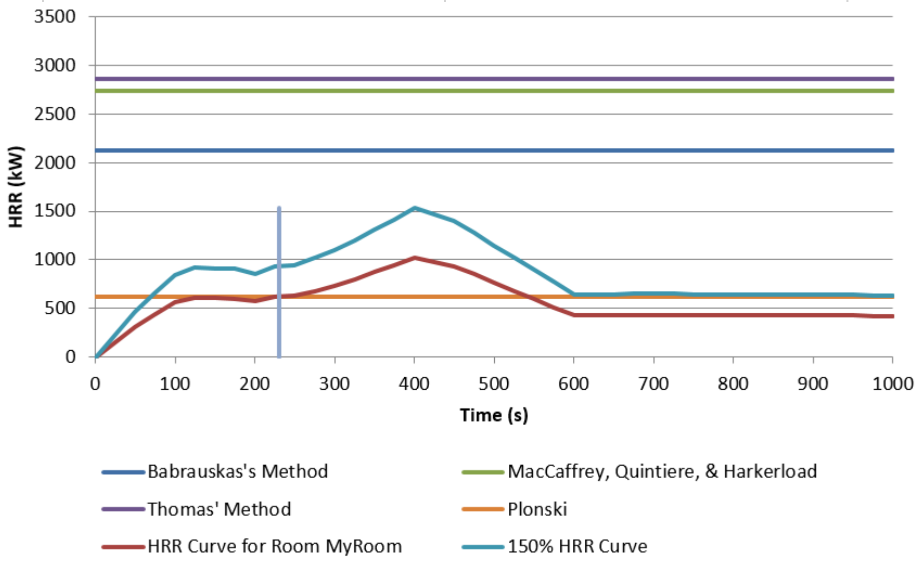
Distance to Sprinkler Head (m)	**2.2**
Sprinkler Head RTI (SI Units)	**80**
Sprinkler Activation Temp (*C)	**74**
Sprinkler Activation Time (s)	230

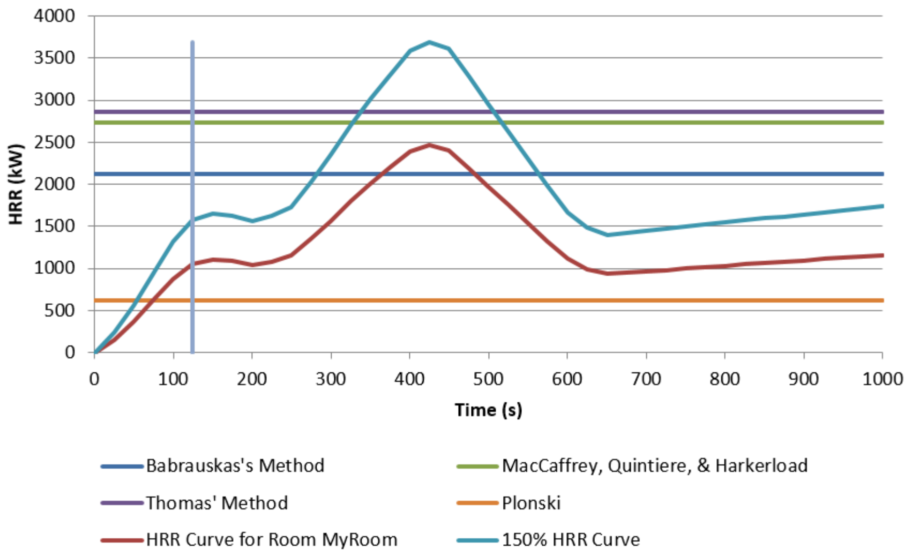


Excel Fire Modeling (Capabilities)

Simulation History

Desk	Computer	Chair	Trash bag	NEW ITEM	Babrauskas	MacCaffrey, et al.	Thomas	Plonski	Total Fire Energy
1,1	1,1	1,1	1,1	0,1	2122 kW	2740 kW	2864 kW	621 kW	565 MJ
3,1	1,1	3,1	1,1	0,1	2122 kW	2740 kW	2864 kW	621 kW	1269 MJ





Excel Fire Modeling (Applications)

Development of CFAST Input File

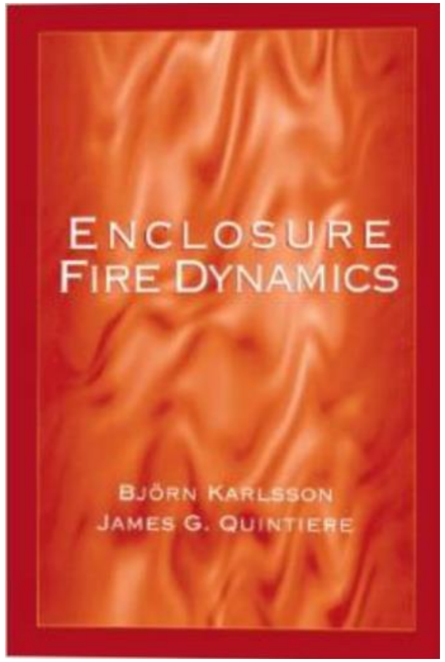
VERSN 5 ROOM MyRoom 100% HRR - HVAC Off	
TIMES 1000 30 30 30 30	
ADUMPF C:\Test\100RmMyRoom.csv WINFS	
DUMPR C:\Test\100RmMyRoom.hi	
TAMB 293.150 101300 0	
EAMB 293.150 101300 0	
#No Wind	
HI/F 0.00000	
WIDTH 4	
DEPTH 12.38	
HEIGH 4	
CXABS 0.00	
CYABS 0.00	
CEILI GYP3/4	
WALLS GYP3/4	
FLOOR CONCRETE	
HVENT 1 2 1 0.91 2.13 0 0 2 0	
CVENT 1 2 1 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.02	<-- 1st room #, 2nd room#, vent#, open fraction
#NO HVAC	<-- Prescribing duct inside of room
#NO HVAC	<-- Prescribing duct outside of room
#NO HVAC	<-- Setting HVAC Flow from inside to outside
CHEMI 100.0000 10.0000 10.0000 2.700E+007 393.150 665.150 0.30000(	<-- Plastic is the assumed fuel
LFBO 1	<-- Fire object in room one
LFBT 2	
TARG 1 FRONT 0.84 0.84 IMPLICIT PDE	
DETECT 2 1 347 2.2 0 4 80 1 0	<--Heat detector/Sprinkler
CJET ALL	
CFCON 1 2	
HHEAT	
FTIME 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000	
FQDOT 0 308883.33325 564016.6665 608816.666416667 571866.666333333 627666.6665 732400 873633.333333333 1024800 935900 763666.7 597533.35 431400	
THRMF C:\NIST\cfast511\thermal.df	

Generate 100%HRR CFAST Input file

Excel Fire Modeling (How it works)

<u>Cumulative HRR Development</u>

- Model identified in Enclosure Fire Dynamics by Karlsson & Quintere



Time (s)	0	25	50	75	100	125	150	175	200	225	250	275	300
Total HRR (kW)	**0.0**	**154.4**	**308.9**	**445.3**	**564.0**	**614.3**	**608.8**	**603.3**	**571.9**	**624.8**	**627.7**	**680.0**	**732.4**
Desk 1	0.0	6.3	12.5	18.8	25.0	31.3	37.5	43.8	50.0	137.5	225.0	312.5	400.0
Computer 1	0.0	4.4	8.9	13.3	17.8	22.2	26.6	31.1	35.5	43.1	50.7	58.2	65.8
Chair 1	0.0	56.3	112.5	168.8	225.0	212.8	200.7	188.5	176.3	164.2	152.0	146.8	141.6
Trashbag 1	0.0	87.5	175.0	244.5	296.3	348.0	344.0	340.0	310.0	280.0	200.0	162.5	125.0

81	100
2.25	225
3.25	325

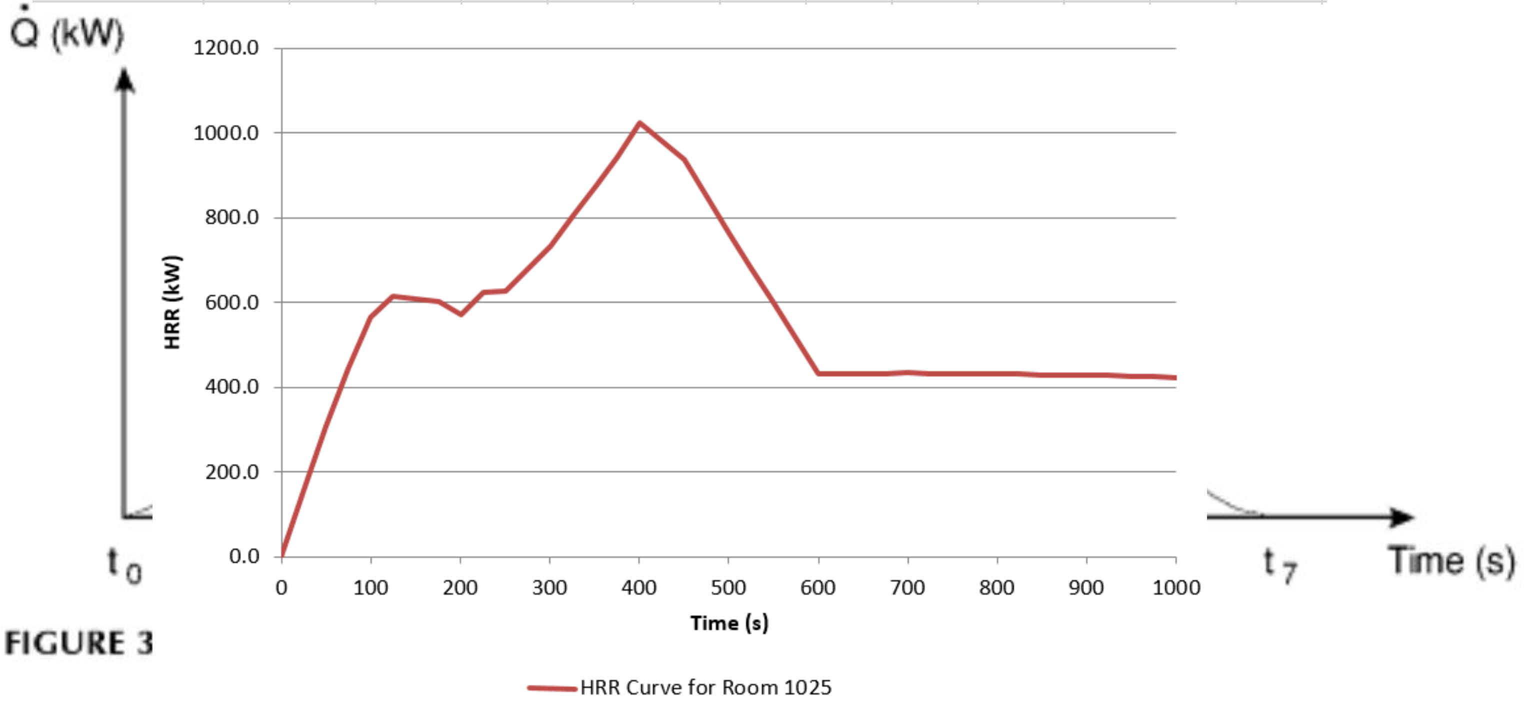


FIGURE 3

Excel Fire Modeling (How it works)

Flashover Correlations **Plus Assumptions**

Babrauskas

$$\dot{Q} = 750 A_0 \sqrt{H_0}$$

Thomas

$$\dot{Q} = 7.8 A_T + 378 A_0 \sqrt{H_0}$$

McCaffrey, Quintiere, and Harkleroad

$$\dot{Q} = 610 (h_k A_T A_0 \sqrt{H_0})^{1/2}$$

where

h_k = effective heat transfer coefficient [(kW/m)/K]

A_T = total area of the compartment surfaces (m^2)

A_0 = area of opening (m^2)

H_0 = height of opening (m)

Excel Fire Modeling (How it works)

Sprinkler/Heat Detector Activation Time

Method of Alpert

$$T_g - T_a = \frac{[5.38(\dot{Q}/r)^{2/3}]}{H} \; ^\circ\mathrm{C}$$

where $r/H > 0.18$, and

$$T_g - T_a = \frac{(16.9\dot{Q}^{2/3})}{H^{5/3}} \; ^\circ\mathrm{C}$$

where $r/H \leq 0.18$, and

$$u = \frac{(0.20\dot{Q}^{1/3}H^{1/2})}{r^{5/6}} \; \mathrm{m/s}$$

where $r/H > 0.15$, and

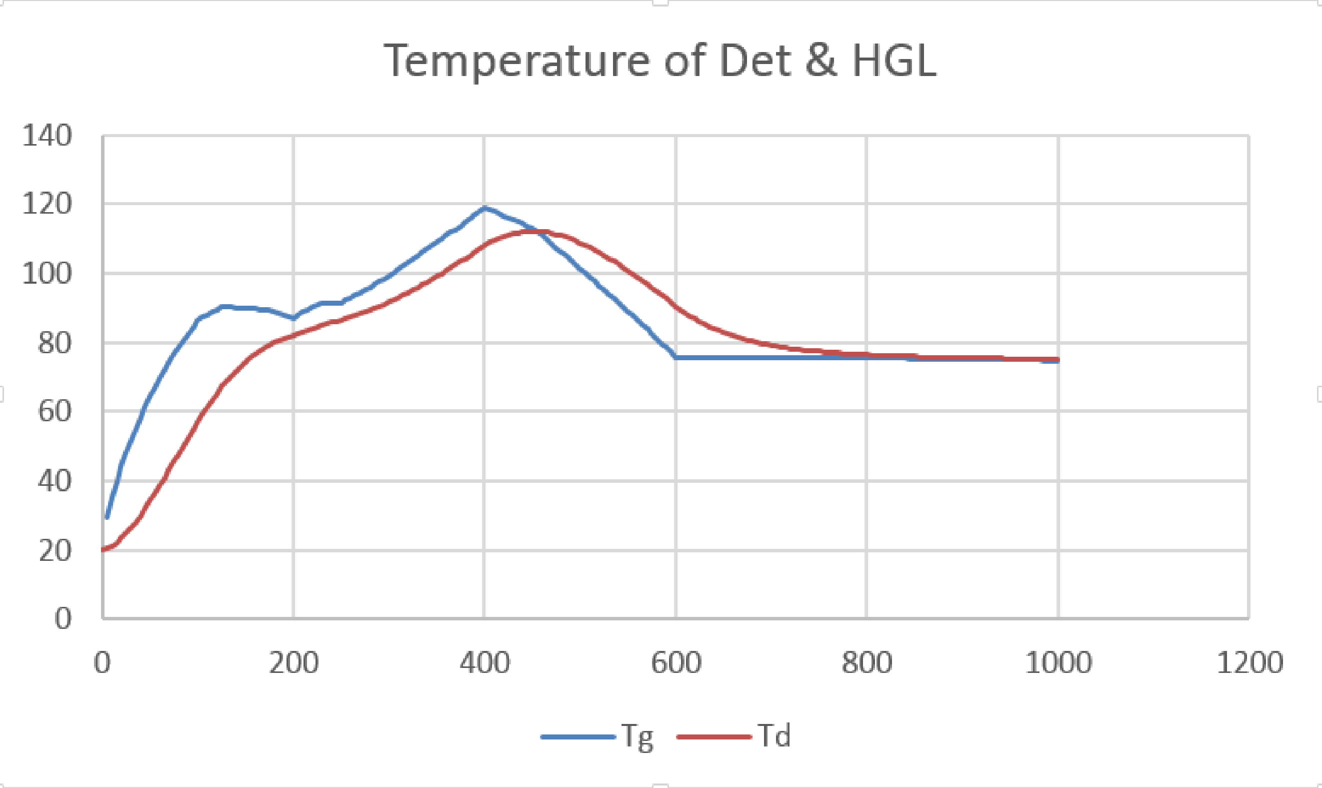
$$u = 0.95\left(\frac{\dot{Q}}{H}\right)^{1/3} \; \mathrm{m/s}$$

where $r/H \leq 0.15$.

$$\Delta T_d = T_d - T_a = (T_g - T_a)\left[1 - \exp\left(\frac{-tu^{1/2}}{\mathrm{RTI}}\right)\right] ^\circ\mathrm{C}$$

Excel Fire Modeling (How it works)

Sprinkler/Heat Detector Activation Time



Excel Fire Modeling (How it works)

Development of CFAST Input File

```
2  VERSN  5 ROOM 1025 100% HRR - HVAC Off
3  TIMES 1000    30    30    30    30
4  ADUMPF C:\Users\calib_000\Google Drive\YourFPE.com\Products\100RmMyRoom.csv WINFS
5  DUMPR C:\Users\calib_000\Google Drive\YourFPE.com\Products\100RmMyRoom.hi
6  TAMB  293.150  101300  0
7  EAMB  293.150  101300  0
8  #No Wind
   1.0 1.0 1.0 1.0 1.0 1.0 0.02      <-- 1st room #, 2nd room#, vent#, open fraction
                                     <-- Prescribing duct inside of room
                                     <-- Prescribing duct outside of  room
                                     <-- Setting HVAC Flow from inside to outside
   .700E+007  393.150  665.150 0.30000(  <-- Plastic is the assumed fuel
                                     <-- Fire object in room one
25 LFBT 2
26 TARG 1 FRONT 0.84 0.84 IMPLICIT PDE
27 DETECT  2 1 347 2.5 0 3 80 1 0     <--Heat detector/Sprinkler
28 CJET ALL
29 CFCON  1  2
30 HHEAT
31 FTIME  50  100  150  200  250  300  350  400  450  500  550  600  650  700  750  800  850  900  950  1000
32 FQDOT  0  308883.33325  564016.6665  608816.666416667  571866.666333333  627666.6665  732400  873633.333333333  1024800  935900  763
33 THRMF C:\NIST\cfast511\thermal.df
```

Generate 100%HRR CFAST Input file

Microsoft Excel

Values from sheet '100% HRR' were created. Do you want me to run CFAST?

Yes | No

Excel Fire Modeling (Limitations)

<u>HRR Database</u>

- 25-Second intervals
- Maximum of 1000 seconds
- Linear interpolation in-between points

<u>Cumulative HRR Development</u>

- 25-Second intervals
- Maximum of 1000 seconds
- Linear interpolation in-between points
- Each combustible-type ignites at time=0
- Next combustible of same type ignites at next time interval (25s, 50s, 75s, etc.)

Excel Fire Modeling (Limitations)

<u>Flashover Correlations</u>

- Babrauskas (**Δ**T=600°C)
  - Based on energy balance of McCaffrey, Quintiere, & Harckleroad
    - Mass outflow proportional to the size of the doorway opening
  - Based on a limited number of experimental test data
  - Assumed primary energy loss to be radiative to 40% wall area at ambient temperature
  - Based on a best fit of a stoichiometric heat release rate for doorway opening
- McCaffrey, Quintiere, & Harckleroad (**Δ**T=500°C)
- Thomas (**Δ**T=600°C)
  - Cubic-shaped rooms

1. The correlation holds for compartment upper layer gas temperatures up to approximately 600°C.
2. It applies to steady-state as well as time-dependent fires, provided the primary transient response is the wall conduction phenomenon.
3. It is not applicable to rapidly developing fires in large enclosures in which significant fire growth has occurred before the combustion products have exited the compartment.
4. The energy release rate of the fire must be determined from data or other correlations.
5. The characteristic fire growth time and thermal penetration time of the room-lining materials must be determined in order to evaluate the effective heat transfer coefficient.
6. The correlation is based on data from a limited number of experiments and does not contain extensive data on ventilation-controlled fires nor data on combustible walls or ceilings. Most of the fuel in the test fires was near the center of the room.

Excel Fire Modeling (Limitations)

Sprinkler/Heat Detector Activation Time

- Quasi-Steady-State
- Falls apart when HRR declines
  - Can produce an unrealistic reduction in temperature

Simulation History

- Maximum of 1000 seconds
- Difficulty in accounting for changes in HRR database

Development of CFAST Input File

- One doorway
- No corridor
- 21 datapoints (HRR timesteps)
- Predefined construction types

Excel/CFAST Integration (Capabilities)

Cumulative HRR Model

- Rapid development of varying HRR models
- Rapid comparison of varied scenarios (total energy released)
- Rapid development of a HRR profile and verification of correct input
- Rapid screening of potential flashover rooms
  - Rapid comparison of different flashover correlations
- Easy identification of separation distance required to preclude radiative ignition
- Simple identification of anticipated heat detector of sprinkler activation time

Excel/CFAST Integration (Capabilities)

Excel/CFAST Integration

- Rapid CFAST input file development
- Adds a user interface to CFAST V3/5
- Allows for rapid changes to CFAST input parameters
- Simple comparison to hand calculations

Excel/CFAST Integration (Looking Forward)

How can this be improved?

- Get it out for feedback!
- HRR database with timesteps < 25-Seconds
- Simulation runtime greater than 1000-Seconds
- Integration with CFAST V6
- Application of a Monte Carlo Simulation
  - Determine other Flashover correlations
  - Analyze model sensitivities
- Post-processing of CFAST output files

Excel/CFAST Integration (Recap)

- Why Excel?
- Capabilities
- How It Works
- Limitations
- Looking Forward

Questions?

Topic: Excel Fire Modeling and CFAST Integration
Presenter: Rob Plonski
Contact: RobPlonski@YourFPE.com

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Excel/CFAST Integration (Link)

Model Here