MODELING OF FIRE IN UNIQUE SPACES OF A NUCLEAR FACILITY

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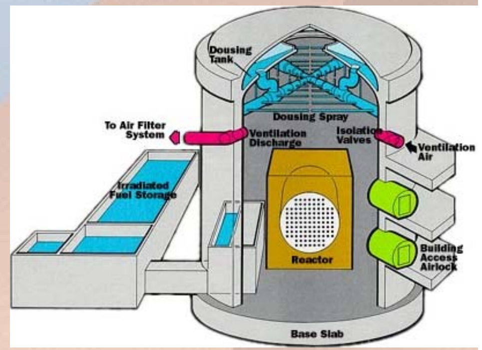
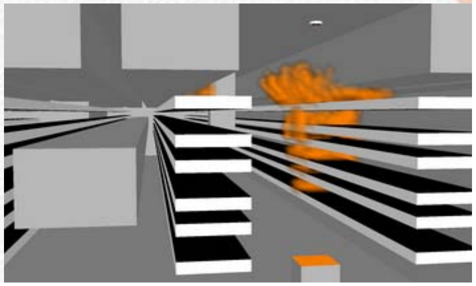
LARGE & UNIQUE SPACES

UNIQUE SPACE EXAMPLES	UNIQUE FEATURES
Turbine Halls (Single & Multi-Unit Plants)	Large spaces, multiple openings between floors / adjacent spaces, high ventilation rates, and special ventilation features.
Reactor Buildings / Vaults	Large space, irregular shape, many openings between rooms/floors.
Control Room Complex	Multiple rooms interconnected, high ventilation rates, and special smoke control features.
Multi-Unit Plant Access-ways	Large space, irregular shape, many openings between rooms/floors, and low combustible loadings.
Cable Spreading Rooms	Large spaces, unique hazard, and high ventilation rates. [Ref: NUREG 6850, Appendix R]
Cable Tunnels & Service Tunnels/Shafts	Unique shape (i.e. High Aspect Ratios)





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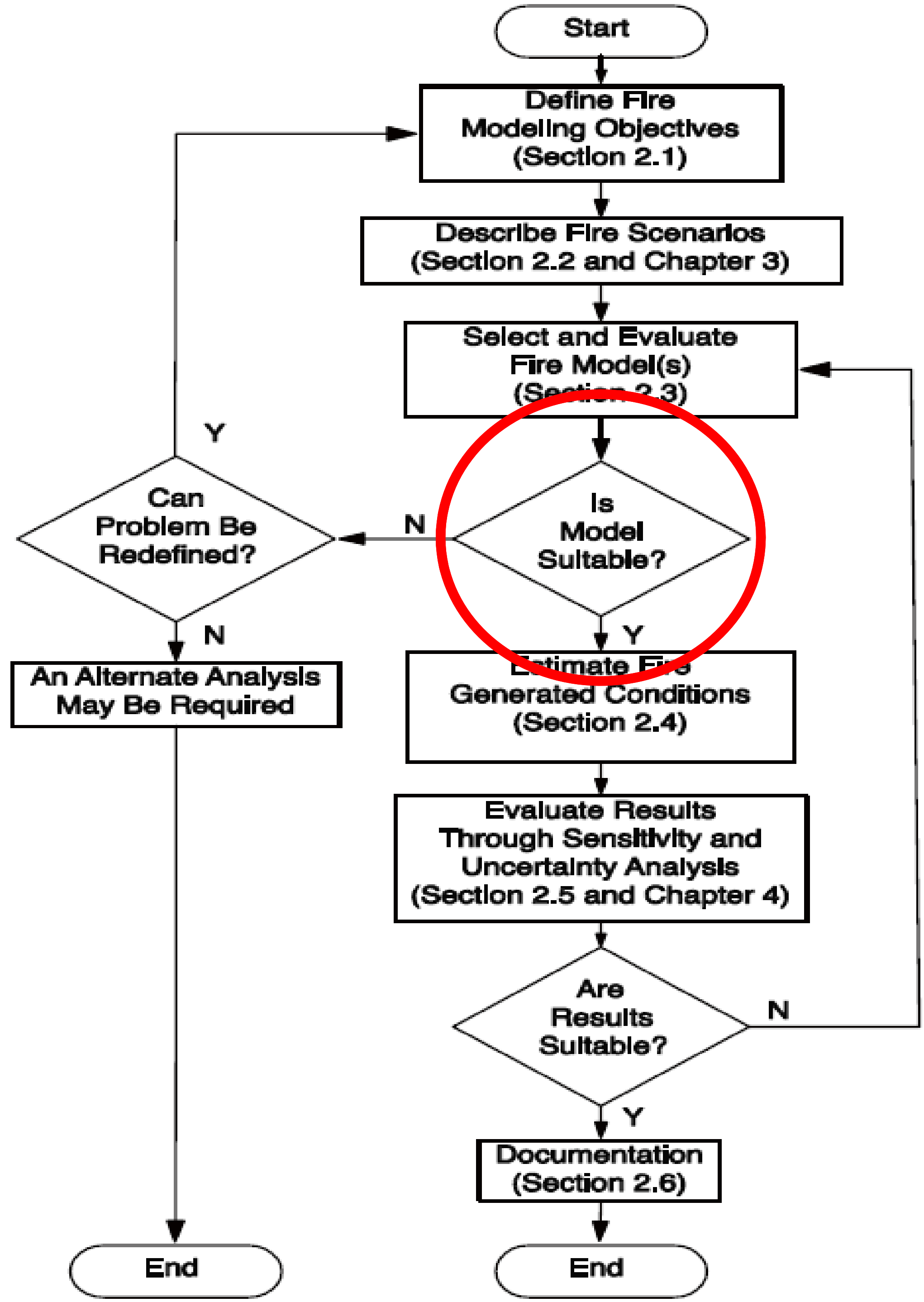
FIRE MODELING PROCESS

NUREG 1934, Nuclear Power Plant Fire-Modeling Application Guide



FIRE MODELING PROCESS

NUREG 1934, Nuclear Power Plant Fire-Modeling Application Guide

NUREG 1824, Chapter 5

NUREG 1824, Chapter 7

Parameters[5]		Fire Model				
		FDTs	FIVE-Rev1	CFAST	MAGIC	FDS
Hot gas layer temperature (“upper layer temperature”)	Compartment of Origin	YELLOW+	YELLOW+	GREEN	GREEN	GREEN
	Adjacent Compartment	N/A	N/A	YELLOW	YELLOW+	GREEN
Hot gas layer (“layer interface height”)		N/A	N/A	GREEN	GREEN	GREEN
Ceiling jet temperature (“target/gas temperature”)		N/A	YELLOW+[2]	YELLOW+	GREEN	GREEN
Plume temperature		YELLOW-	YELLOW+[2]	N/A	GREEN	YELLOW
Flame height[3]		GREEN	GREEN	GREEN	GREEN	YELLOW[1]
Oxygen concentration		N/A	N/A	GREEN	YELLOW	GREEN
Smoke concentration		N/A	N/A	YELLOW	YELLOW	YELLOW
Compartment pressure[4]		N/A	N/A	GREEN	GREEN	GREEN
Target temperature		N/A	N/A	YELLOW	YELLOW	YELLOW
Radiant heat flux		YELLOW	YELLOW	YELLOW	YELLOW	YELLOW
Total heat flux		N/A	N/A	YELLOW	YELLOW	YELLOW
Wall temperature		N/A	N/A	YELLOW	YELLOW	YELLOW
Total heat flux to walls		N/A	N/A	YELLOW	YELLOW	YELLOW

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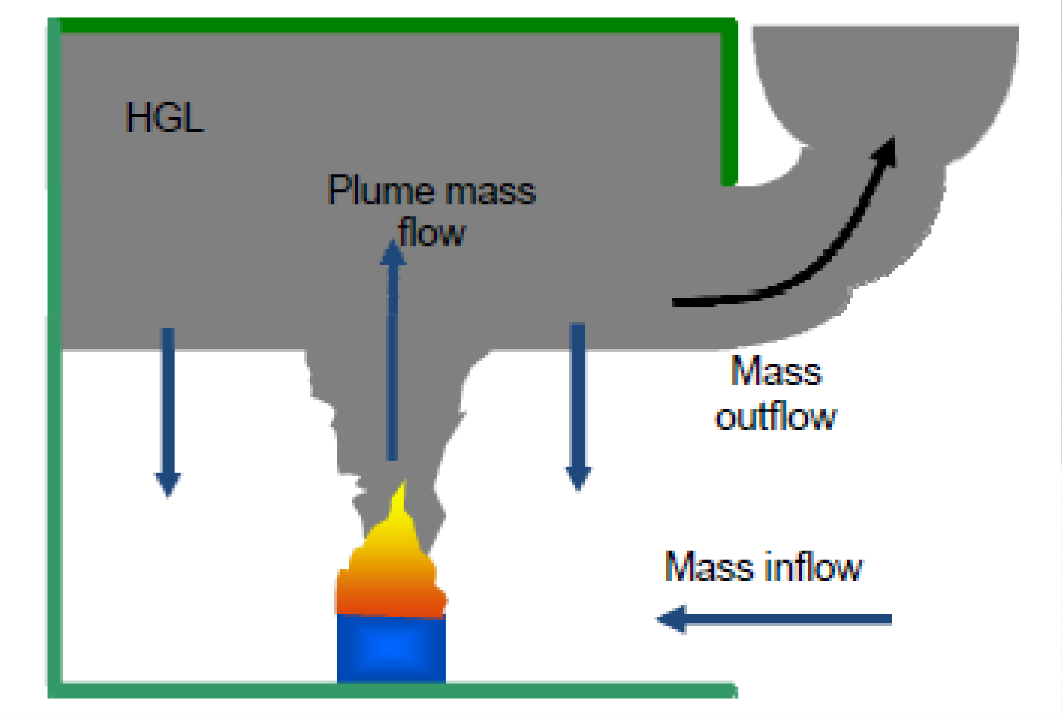
CFAST FIRE MODELING SOFTWARE

- Two control volumes (Hot upper gas layer & cool lower layer).
- Each zone has uniform properties that change with time.
- Applicable for most fire parameter calculations [NUREG 1934].
- Simple to use and provides quick results.
- Ability to perform multiple parameter sensitivity studies.

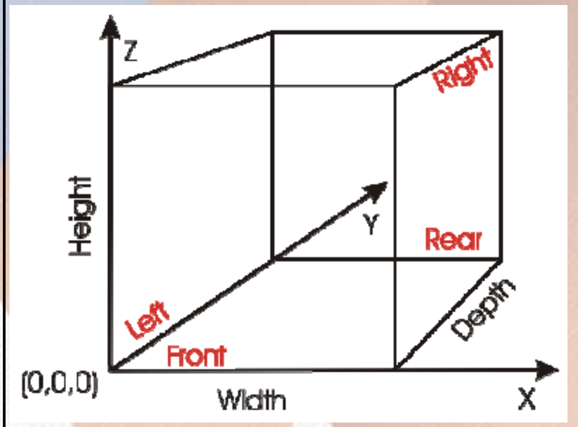
NUREG 1934, Nuclear Power Plant Fire-Modeling Application Guide

CFAST – Consolidated Model of Fire Growth and Smoke Transport (Version 6) Technical Reference Guide



CFAST INPUTS – COMPARTMENTS

MODELING ELEMENT	USE & LIMITATION
Compartment Geometry	Generally limited to simple compartment spaces (i.e. rectangular shaped). This model is not intended to include complex geometries where a complex flow field is a driving force. Error increases with increasing deviation from a rectangular shape [NUREG 1934]. CFAST Warning/Error Message when compartment dimension exceeds 100 m. The model can still be run but should be reviewed for validity. The use/limits of the model are more a function of the fire size relative to the compartment. All walls are represented by the same boundary materials (kpc).



NUREG 1824, Chapter 5

NUREG 1934

CFAST Technical Reference Guide

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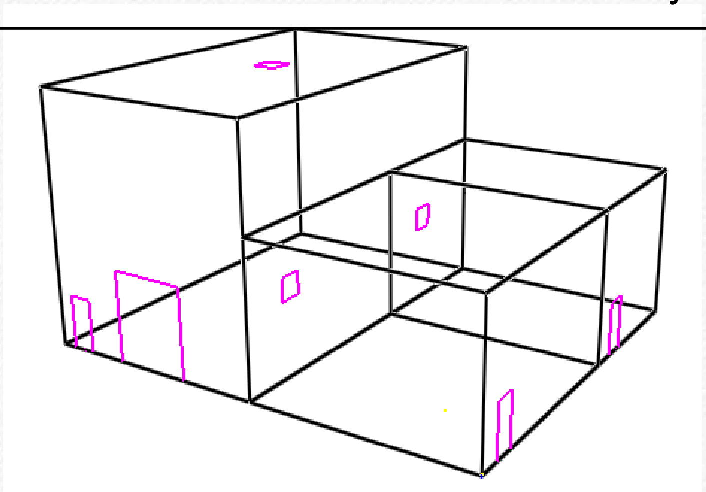
CFAST INPUTS - VENTILATION

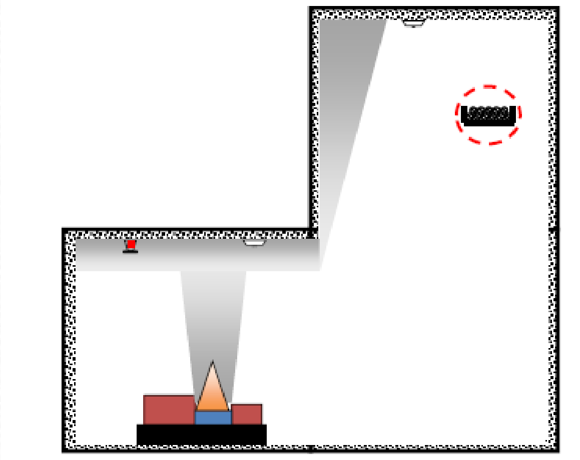
Horizontal Flow Vents
- Doors
- Windows
- Penetrations / Leakage Estimates

Vertical Flow Vents
- Natural vents/openings
- Floor hatches/openings

Mechanical Flow Vents
- Fresh air or Recirculated
- Fire / Smoke Controls
- Fire Dampers / Louvers

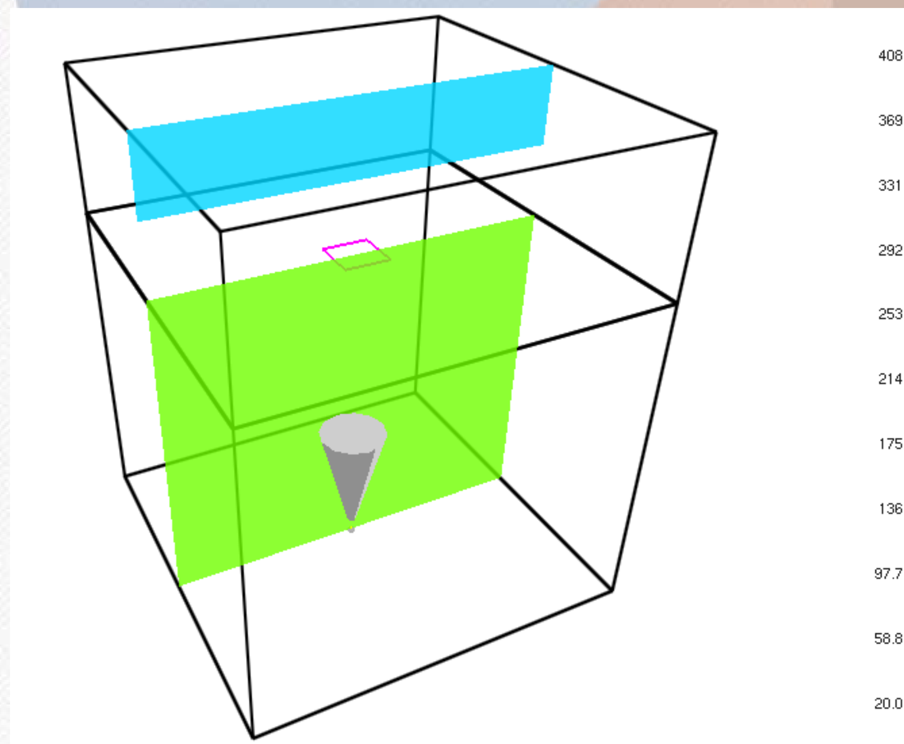
USE & LIMITATION
Natural vertical openings such service openings, doors, windows, etc. can be shown in multiple locations but horizontal openings in the floor/ceiling need to summed to one vent. Caution is required when modeling large openings between two rooms or spaces with different geometries within the same room. The entrainment correlations used by the zone model to handle vertical vents were not designed for such large openings. CFAST Warning/Error Message when mechanical ventilation exceeds 10 air changes per hour. The model can still be run but should be reviewed for validity.





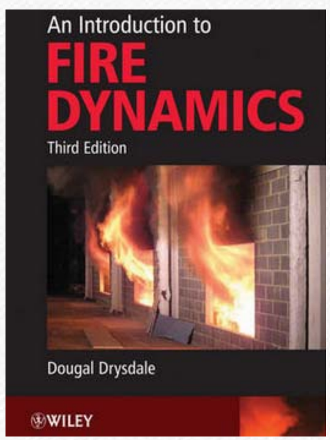
CFAST INPUTS – FIRE OBJECT(S)

- Combustible Materials (Δh_c, Δh_g, A_{FIRE}, $\dot{m}$, V_p)
- Location
- Fire growth rate
- Peak Heat Release Rate
- Steady Burning Period
- Fire duration



References:

- SFPE Handbook
- Drysdale - Intro to Fire Dynamics
- NUREG 1805
- NUREG 6850



CFAST INPUTS – FIRE OBJECT(S)

MODELING ELEMENT	USE & LIMITATION
Fire Heat Release Rate (HRR) Curve	HRR and fire growth is specified by the User. The model will limit the HRR based on available oxygen. The User needs fire dynamics training to specify fire inputs that will represent a realistic fire scenario (i.e. source, fire spread and growth rate, etc.). CFAST guideline suggests a maximum limit of 1 MW/m^3. From fire modeling experience, this limit was never reached for compartment fire modeling.

$$\dot{Q}_{max,FA} = \frac{\rho_{air} H_{air} X_{ACH} V_{Room}}{3{,}600}$$

$$\dot{Q}_{max,NV} = 3{,}000\, \dot{m}_{air} = 3{,}000\, [0.5 A_O \sqrt{H_o}\,]$$

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ASSUMPTIONS & SENSITIVITY ANALYSIS

UNIQUE SPACE EXAMPLES	SIMPLIFIED ASSUMPTION	POTENTIAL ERRORS
Irregular room shape with constant ceiling height	Volume = Constant Height = Constant	Depending on the fire location, the thermal exposures calculated in the fire model may be less / more severe than what would be actually expected.
Irregular room shape with variable ceiling heights	Volume = Constant Height = Average Value	
Wall boundary materials are not uniform	Use the boundary material with the kρc value that	Less heat loss through the boundaries resulting in higher temperatures in the compartment.
Rooms that contain numerous combustible materials of varying fire severity.	Use a weighted average to define the fire inputs in terms of fire growth rate and heat of combustion.	Fire modeling results could vary, depending on what materials are actually initially involved. More than one scenario needed to determine possible fire impacts.
	Use the most severe materials to define the fire inputs in terms of growth rate, heat of combustion, etc.	

ASSUMPTIONS & SENSITIVITY ANALYSIS

UNIQUE SPACE EXAMPLES	SIMPLIFIED ASSUMPTION	POTENTIAL ERRORS
Rooms with minimal / negligible Combustible Hazards.	Transient combustibles could be present in all rooms. Ignition is assumed to occur.	Fire severity of transient combustibles is dependent on the materials used, storage arrangement and storage location. Use conservative assumptions to err on the side of caution.
Rooms with high combustible loading which will support peak combustion for many hours.	Fire duration times used in fire modeling is typically less than the theoretical duration to consume the entire combustible content of a room.	If the fire duration times are too short, the fire modeling results may not reflect worst case fire related consequences. If the time is too long, the fire modeling results may over predict the fire related consequences.
Large spaces with high ceilings.	CFAST fire modeling outputs provide an average Hot Gas Layer (HGL).	For large spaces with high ceiling ceilings containing major fire hazards, the significant hot gas layer depth could occur. This result may under-predict the thermal exposures at the ceiling level. Other calculations may be needed to evaluate the thermal exposure at the ceiling level.

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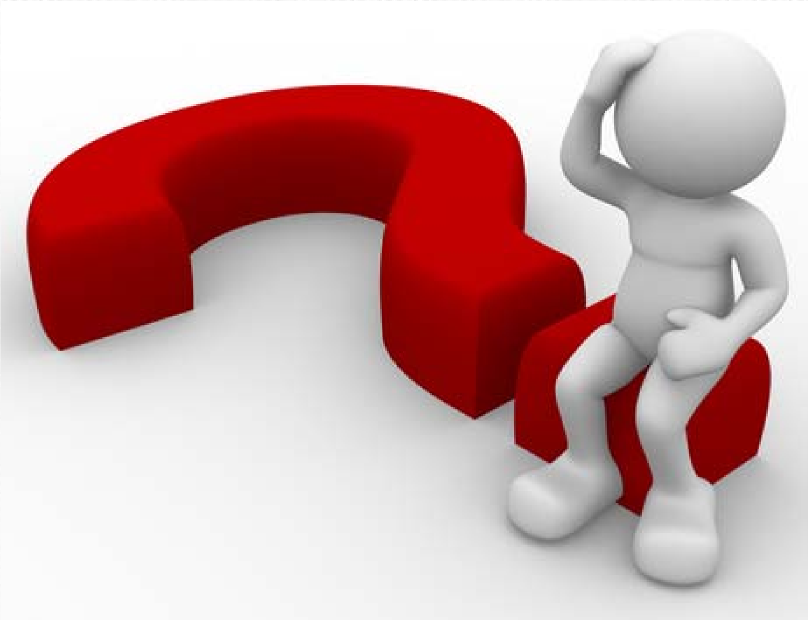
QUESTIONS?



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