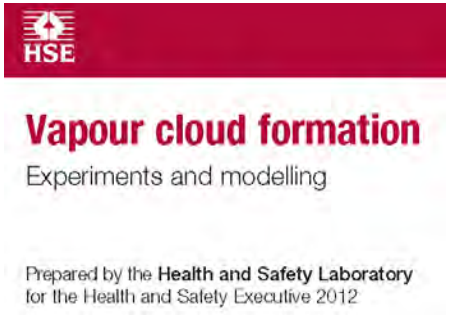
Latest Research Results for Gasoline Tank Overfill Vapor Clouds

PEMY Consulting
Philip Myers - phil@pemyconsulting.com
National Institute for Storage Tank Management September 19,2013
Houston Texas,
Double Tree by Hilton Hotel Houston Hobby Airport

Most Recent Work

- Funded by UK HSE
- Research Report 908
- PSLG Final Report



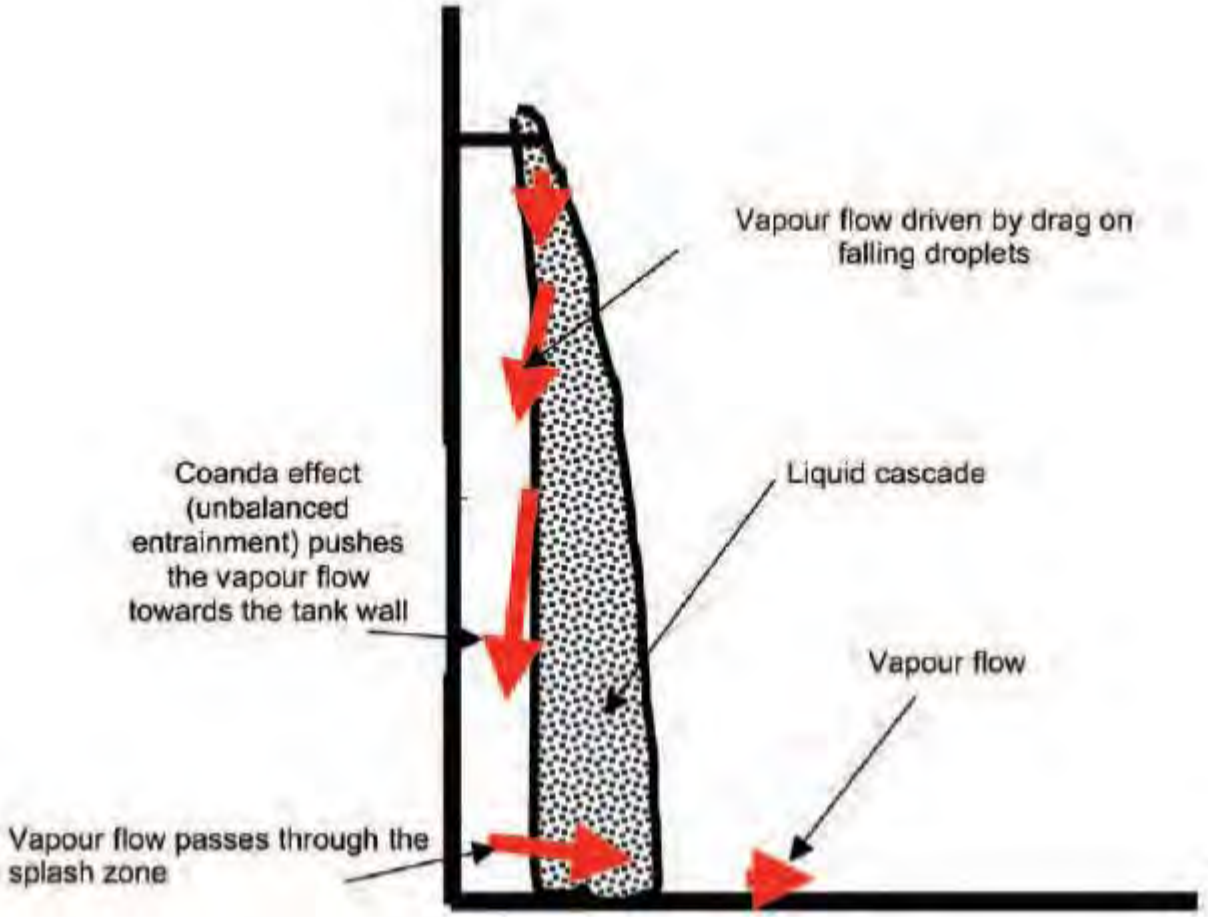
- But hard to use and interpret

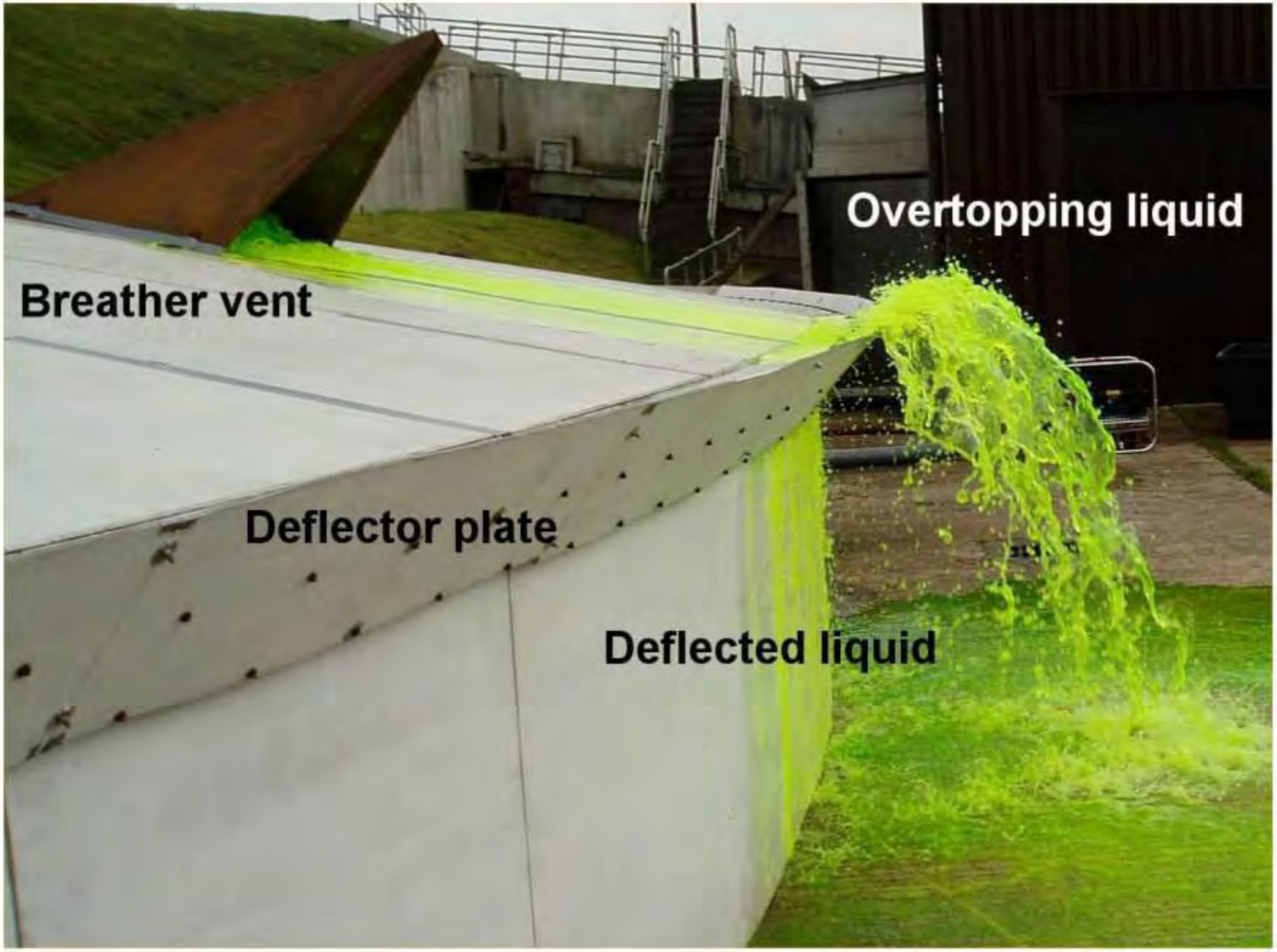
HSE Model Simple (can do on calculator) But what are the right Inputs?

- Diameter
- Height
- Flow rate
- Air temp
- Fuel temp
- Release duration

- Answer: There is no “right input” – how can we use the HSE Model

Basic Model and Test Set Up




Overtopping liquid
Breather vent
Deflector plate
Deflected liquid

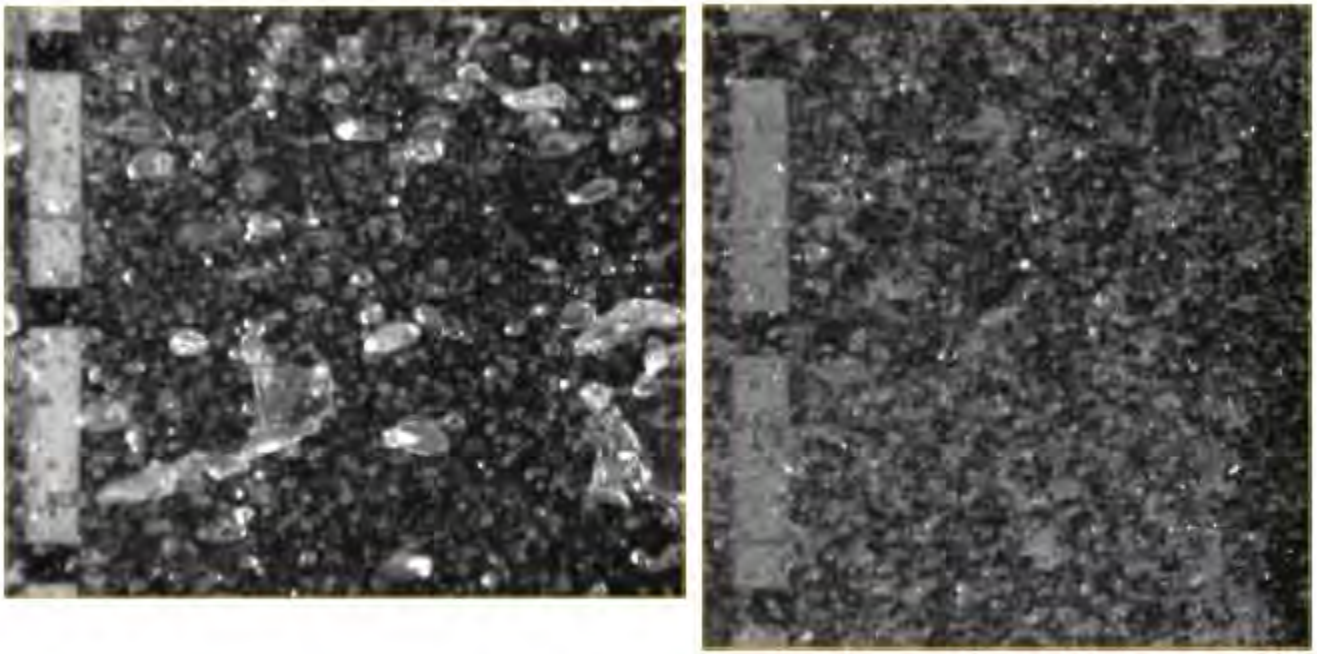
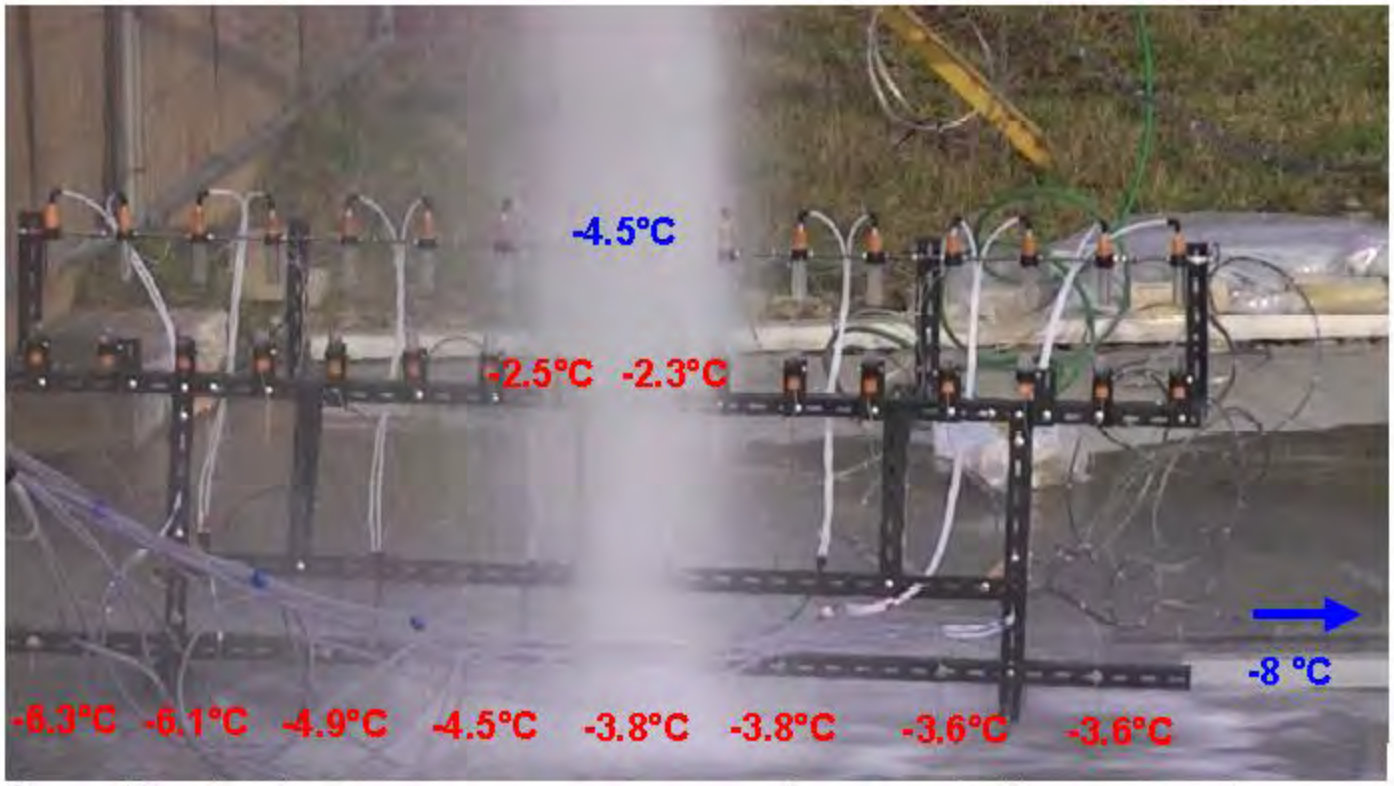
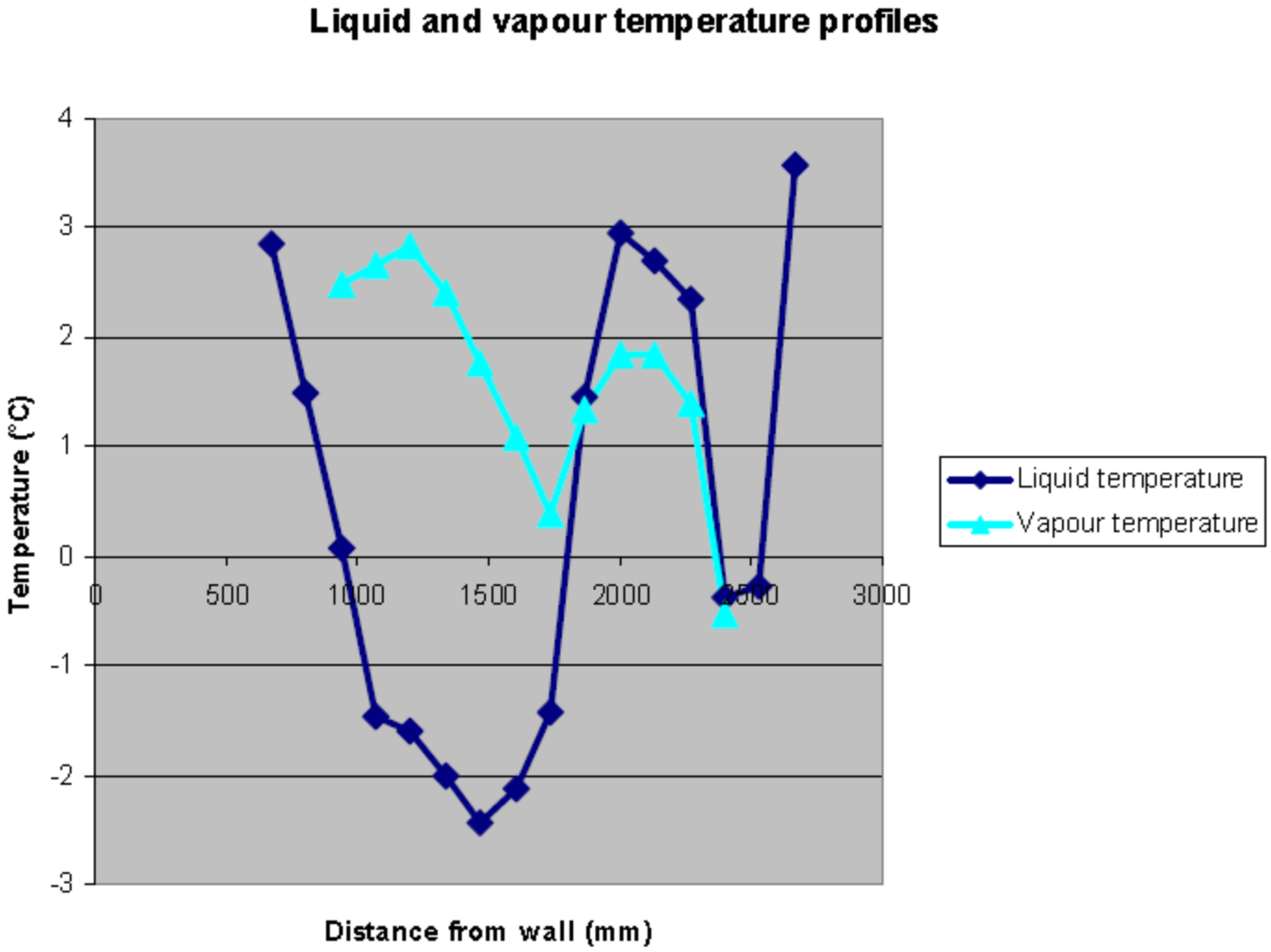
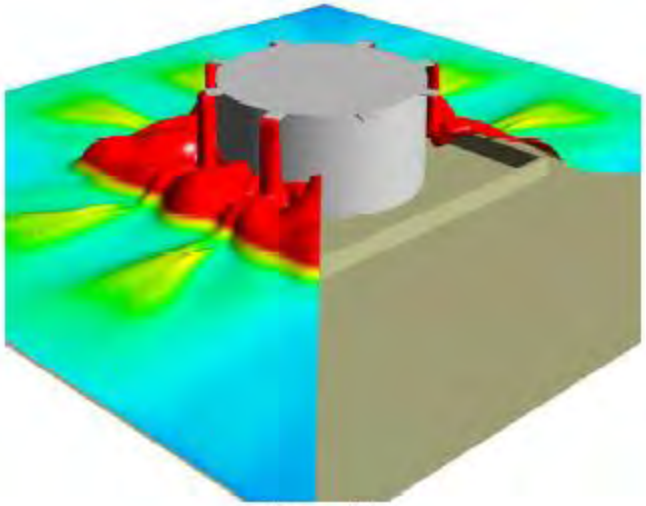


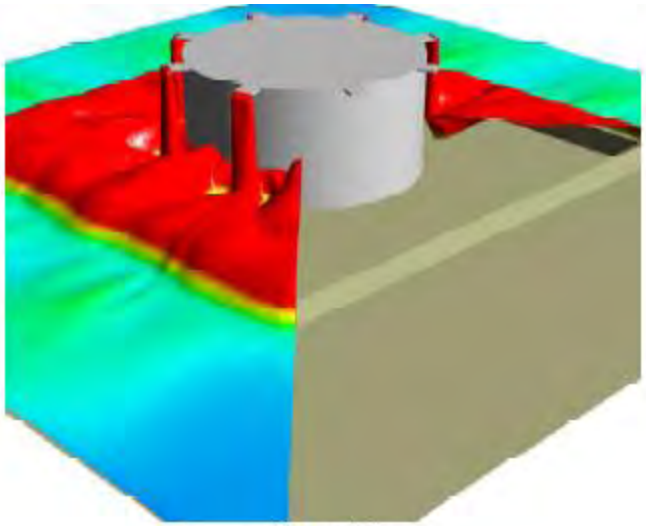
Figure 14b: Comparison between cascade droplet structure in water (left) and decene (right) in similar conditions


-4.5°C
-2.5°C
-2.3°C
-8 °C
-6.3°C
-6.1°C
-4.9°C
-4.5°C
-3.8°C
-3.8°C
-3.6°C
-3.6°C

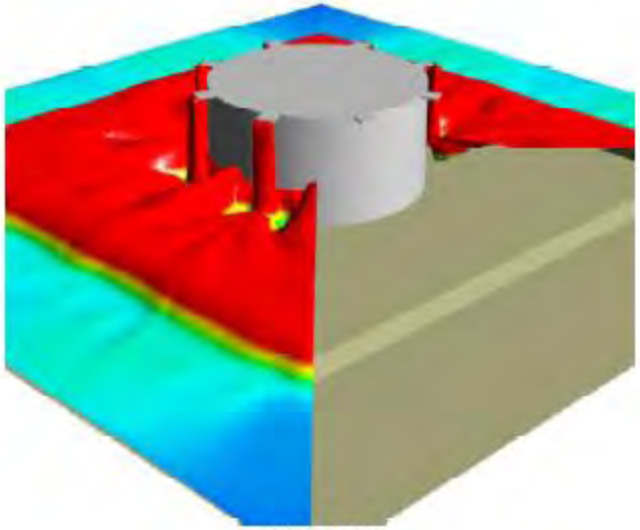

Liquid and vapour temperature profiles
Temperature (°C)
4
3
2
1
0
-1
-2
-3
0
500
1000
1500
2000
2500
3000
Distance from wall (mm)
Liquid temperature
Vapour temperature



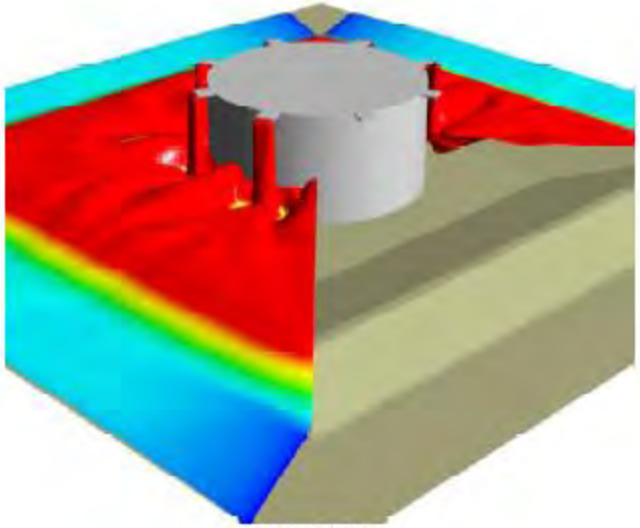
Case D



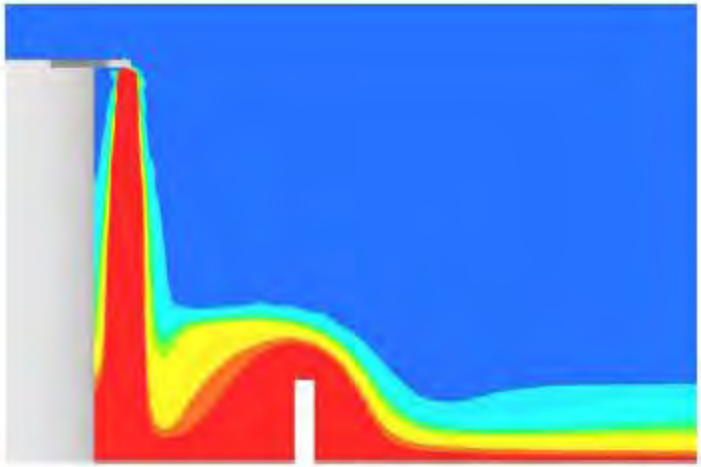
Case E



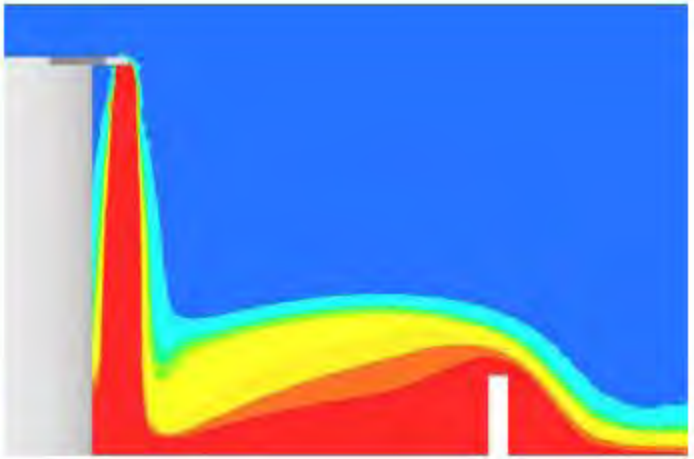
Case F



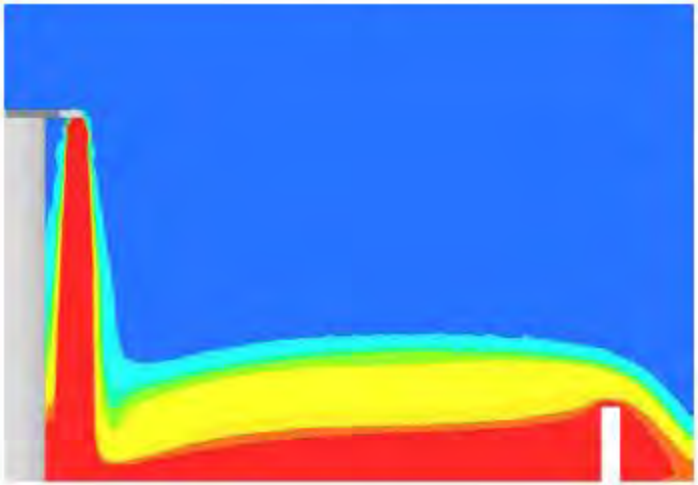
Case G



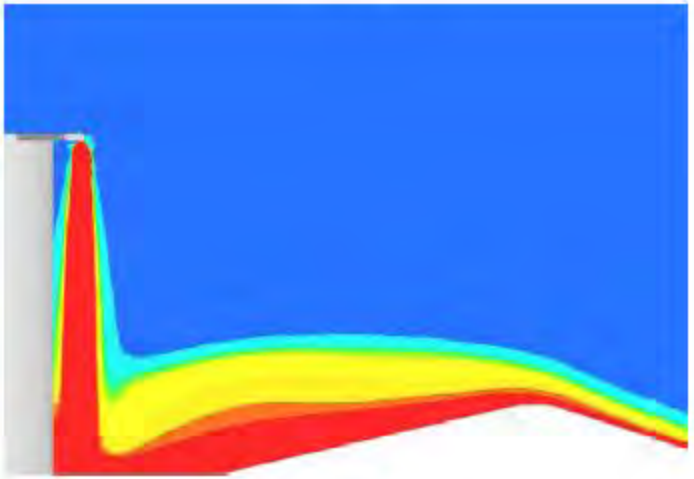
Case D



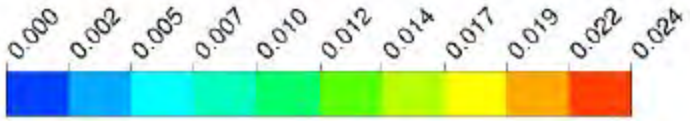
Case E



Case F



Case G



What to do?

- Look at individual tank
- Look at likelihoods on average

HSE Model Simple (can do on calculator)
But what are the right Inputs?
What to do?

- Diameter
- Height
- Flow rate
- Air temp
- Fuel temp
- Release duration
- Answer: There is no “right input” – how can we use the HSE Model

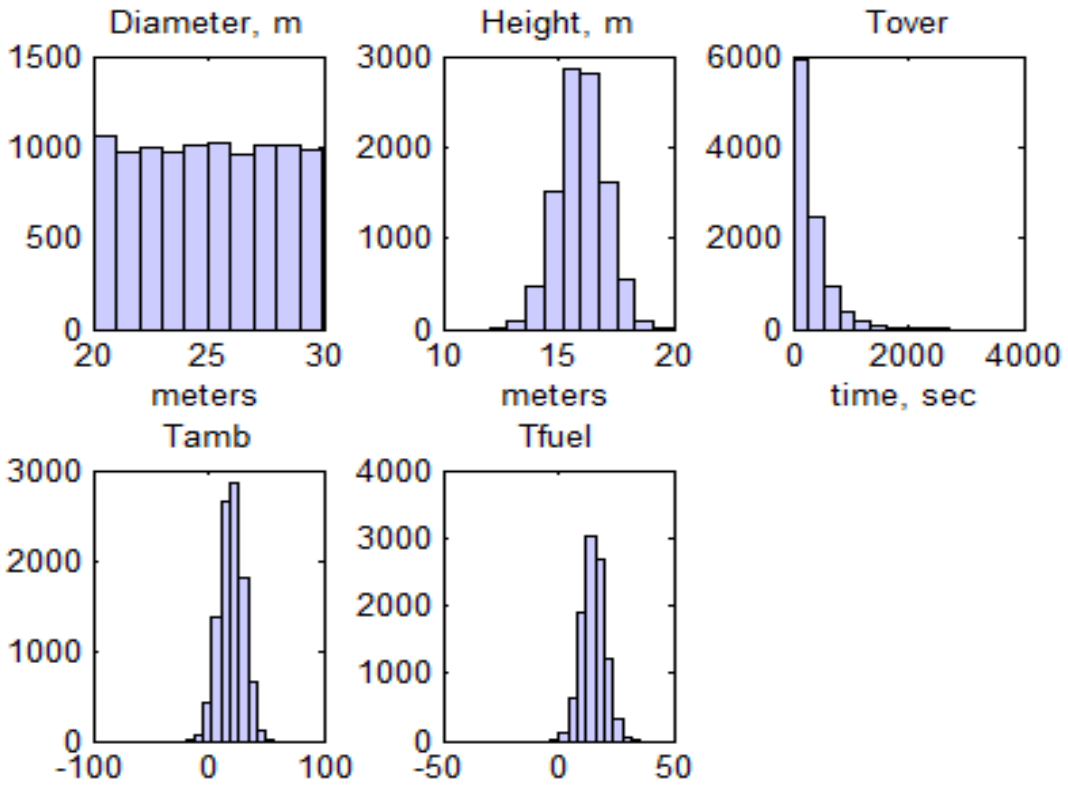
- Look at individual tank
- Look at population of tanks
- Look at likelihood on a population and societal (regulatory impacts)

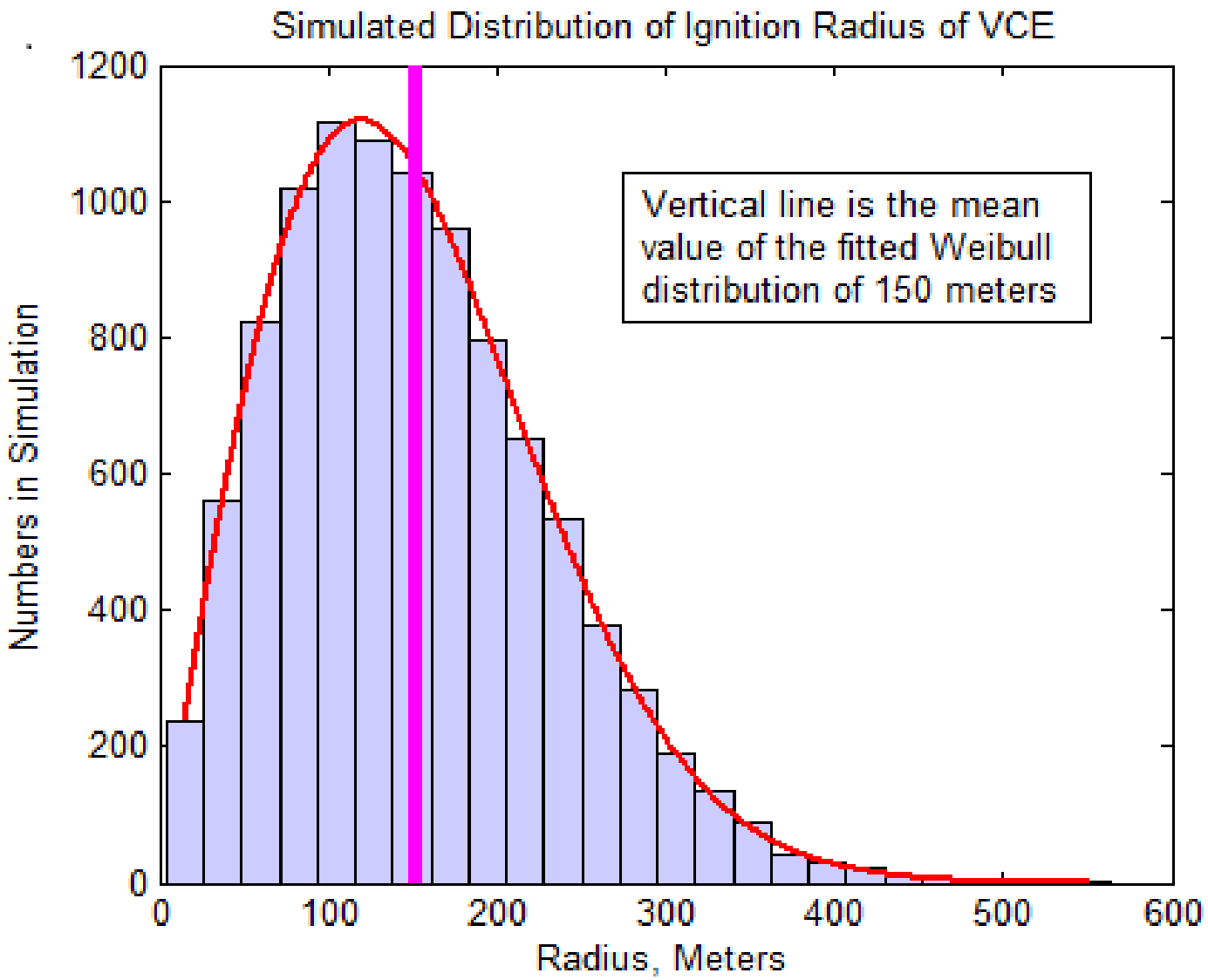
Table 1 Validation Calculation		
Variable	RR908	Validation
Input variables		
D, tank diameter, meter	25	25
H, tank height, meter	15	15
F, fuel flow rate, kg/s	115	115
Tfuel, fuel temp, deg C	14	14
Tamb, ambient air temp, deg C	0	0
T, duration of release, sec	1400	1400
Calculated variables		
Mass entrainment in cascade, kg/s	108	108.0149
Concentration at tank foot, mass fraction	.153	0.1545
Mass vaporized, kg/s	19.5	19.7434
Mass splashed, kg/s	2.2	2.3000
Mcloud, mass addition rate to cloud, kg/s	259	260.1166
Vcould, vol addition rate to cloud, m3/s	199	199.8591
Conc of fuel vapor in cloud , kg/m3	0.11	
Results of interest		
Rescape, meter	210	211.0260

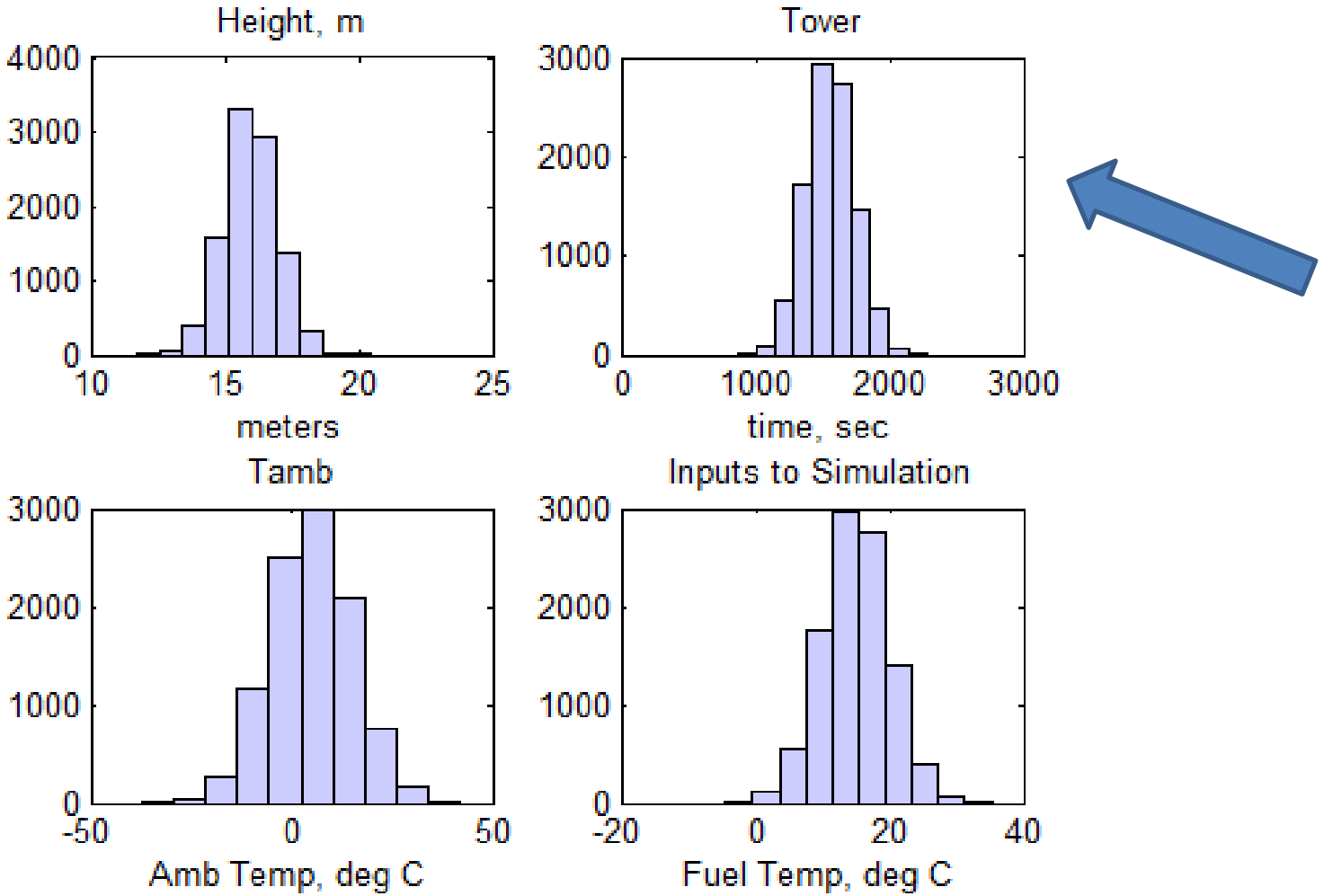
Table 2 Calculation for Puerto Rico	
Variable	Values
Input variables	
D, tank diameter, meter	45
H, tank height, meter	16
F, fuel flow rate, kg/s	320
Tfuel, fuel temp, deg C	14
Tamb, ambient air temp, deg C	0
T, duration of release, sec	1560 **(26 minutes)**
Calculated variables	
Mass entrainment in cascade, kg/s	223.1844
Concentration at tank foot, mass fraction	0.1751
Mass vaporized, kg/s	47.3804
Mass splashed, kg/s	6.4000
Mcloud, mass addition rate to cloud, kg/s	553.9297
Vcould, vol addition rate to cloud, m3/s	425.6087
Conc of fuel vapor in cloud , kg/m3	0.1264
Results of interest	
Rescape, meter	**325.0705**
Rignition, meter	**459.7192**
Actual ignition radius, meters (see above)	**371**

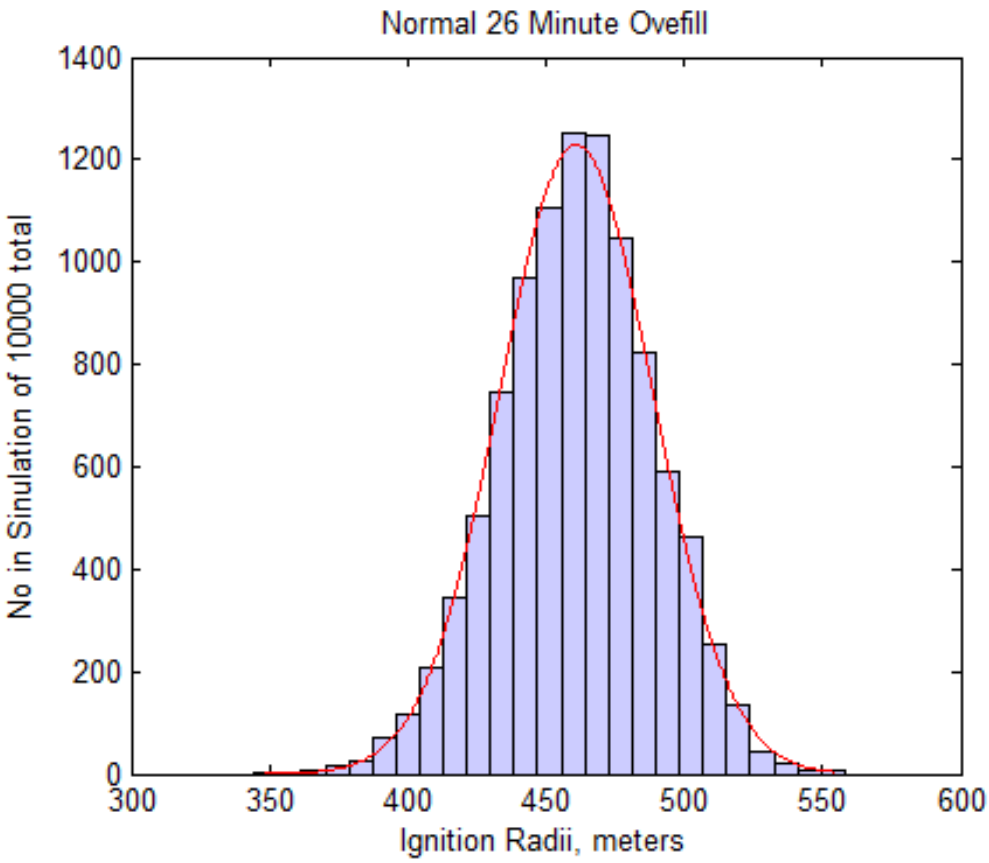
"Radius" of Vapor Cloud for Puerto Rico about 371
vs calculated of 325.
This is good agreement!

For one tank with many conditions or many tanks with many conditions use Monte Carlo Simulation




Simulated Distribution of Ignition Radius of VCE
Vertical line is the mean value of the fitted Weibull distribution of 150 meters
Numbers in Simulation
Radius, Meters
0
200
400
600
800
1000
1200
0
100
200
300
400
500
600


Height, m
4000
3000
2000
1000
0
10
15
20
25
meters
Tover
3000
2000
1000
0
0
1000
2000
3000
time, sec
Tamb
3000
2000
1000
0
-50
0
50
Amb Temp, deg C
Inputs to Simulation
3000
2000
1000
0
-20
0
20
40
Fuel Temp, deg C


Normal 26 Minute Ovefill
No in Sinulation of 10000 total
Ignition Radii, meters
0
200
400
600
800
1000
1200
1400
300
350
400
450
500
550
600

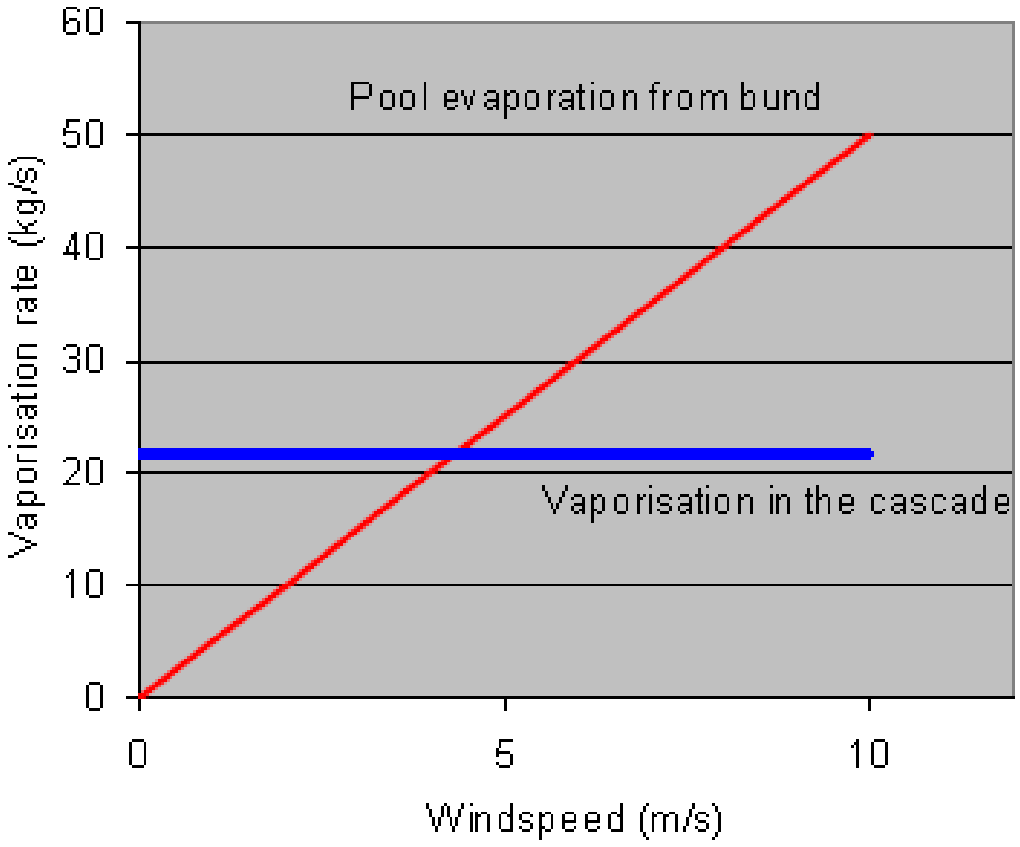
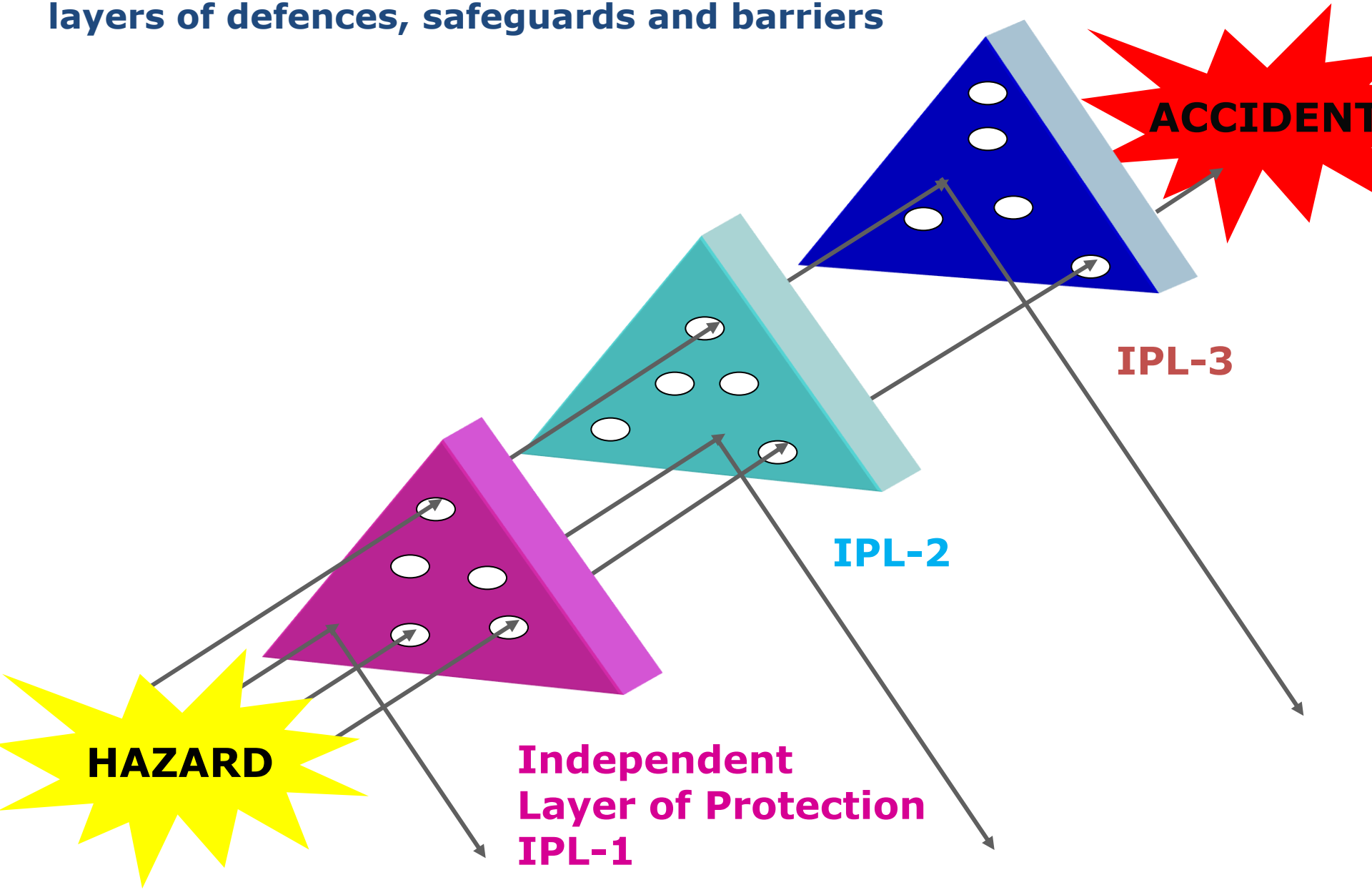

60
50
40
30
20
10
0
Vaporisation rate (kg/s)
Pool evaporation from bund
Vaporisation in the cascade
0
5
10
Windspeed (m/s)

Diagram based on James T. Reason's Swiss Cheese Model which shows successive layers of defences, safeguards and barriers



Summary and Conclusion

- Like any serious bad incident a unique combination of circumstances must happen (i.e. the Harry Reason "swiss cheese diagram"
- But these bad events do happen – so the question is – is it going to happen to you?
- Risk management is the key. Simple risk matrices and what if type analyses are not good enough. Semi quantitative methods as a minimum (fault trees, event trees, bayes nets, etc)
- But, really, all of these best practices covered by API 2350 – so use it!