DNV·GL

OIL & GAS

Detonation – Evidence from Explosion Incidents

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Overview

- Background and context
- Evidence for DDT and sustained detonation in vapour cloud explosions
  - Experimental data
  - Incidents
- Why it matters

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History - Large Scale Experimental Studies

- DNV GL Spadeadam Testing & Research Centre

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History - Large Scale Experimental Studies

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- Large scale vapour cloud explosion experiments
  - 45 m long test rig
  - Flame acceleration in congestion generates pressure

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History - Large Scale Experimental Studies

- DNV GL Spadeadam Testing & Research Centre
- Large scale vapour cloud explosion experiments
  - 45 m long test rig
  - Flame acceleration generates pressure
- Tests with propane & cyclohexane
  - Flame acceleration to Mach 2
  - Deflagration to detonation transition (DDT)
  - Sustained in open cloud

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History

- The concept of DDT in 'real' VCEs with common hydrocarbons was not accepted.
- Industry settled on deflagrations in well defined congested regions
- Reasons given why DDT not considered relevant?

"Detonation would not be sustained in open cloud"

"Conditions required would never be realised in a real incident"

"Damage from DDT would be much more severe than observed"

"How can I possibly design against a detonation!!"

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But then….

- Buncefield UK 2005
- Overfilling of gasoline tank
- Major vapour cloud explosion
- Damaged many storage tanks resulting in major fire
- Considerable civil damage claims

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Overpressure Damage

Very little process congestion

Dense vapour cloud covering large area, much of it off-site

Widespread severe blast damage within the uncongested parts of the vapour cloud

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Jaipur – October 2009

1000 Tonnes of gasoline spilled

Major vapour cloud explosion

Cloud area 3 times that of Buncefield

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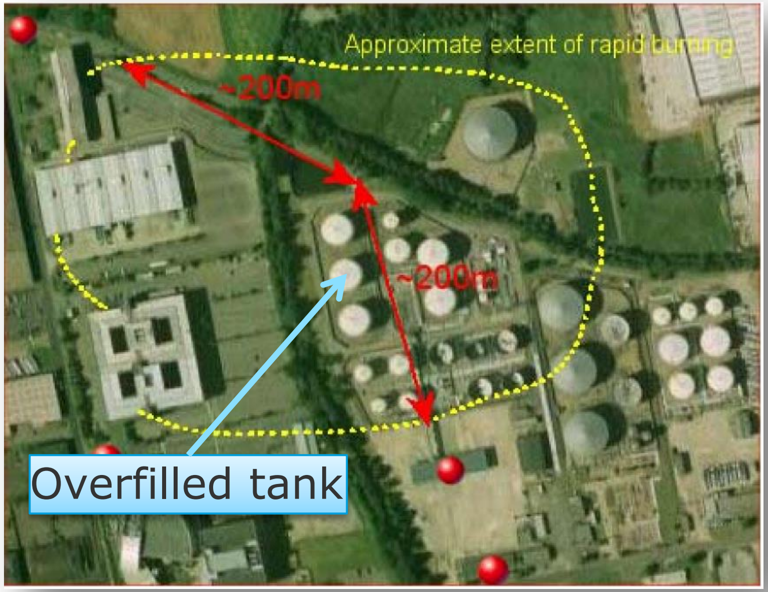
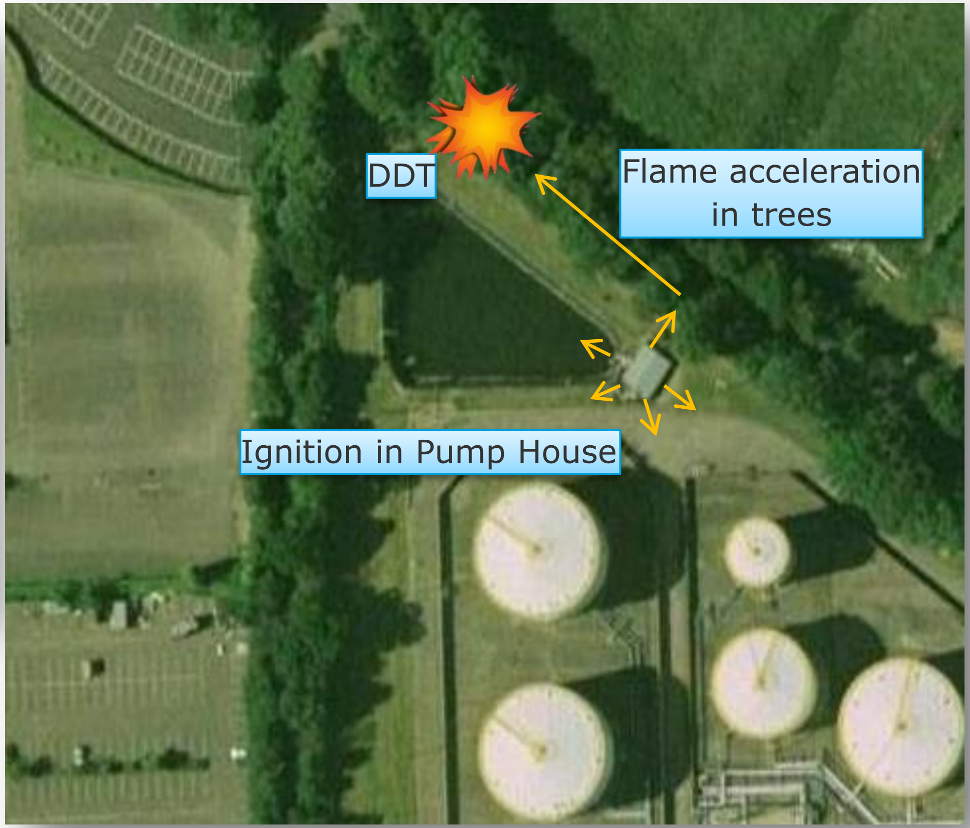
Buncefield





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Research

- Need to demonstrate that DDT is possible in the conditions in these incidents

- But this is not sufficient….. We need to examine the evidence in more detail.

- We need to show that the evidence occurs if <u>and only if</u> DDT has occurred

- As we will see, there is a qualification to this

Showing DDT is Possible

- Experiments in tree congestion:
  - **Low density:**
    - Reaches limiting flame speed at sub-sonic
    - Low pressures
  - **High Density:**
    - Continuous flame acceleration to DDT
    - Short distance of flame propagation – as little as 12m from point of ignition
    - Sustained when flame emerged from vegetation

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Evidence from Incidents

- CCTV records – helpful but not decisive
- Pressure damage – inside and outside the vapour cloud
- Directional indicators

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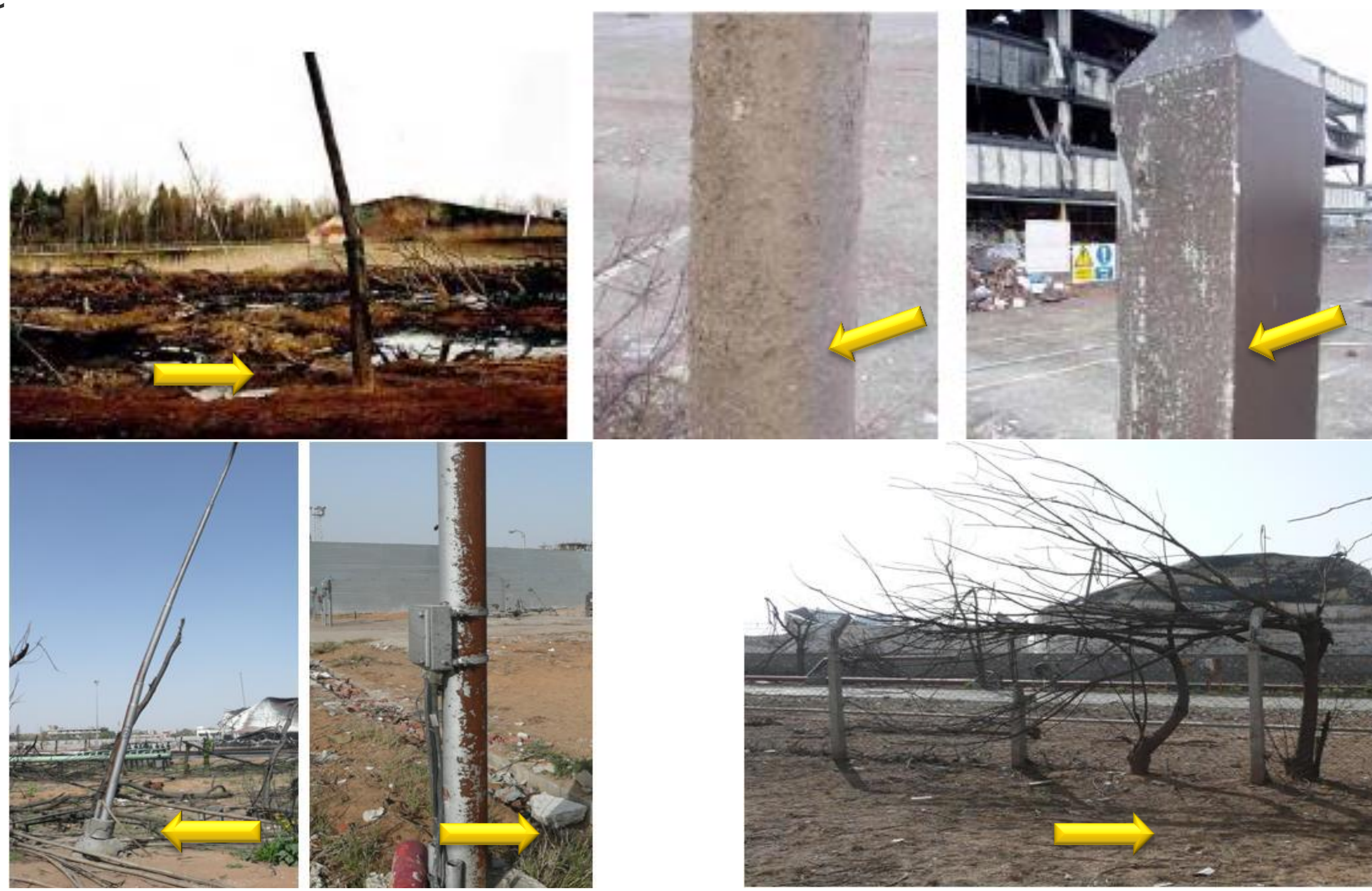
Directional Indicators

- Critical evidence inside the cloud
- Arrow gives direction of explosion
- Reverse expanding flow is the cause



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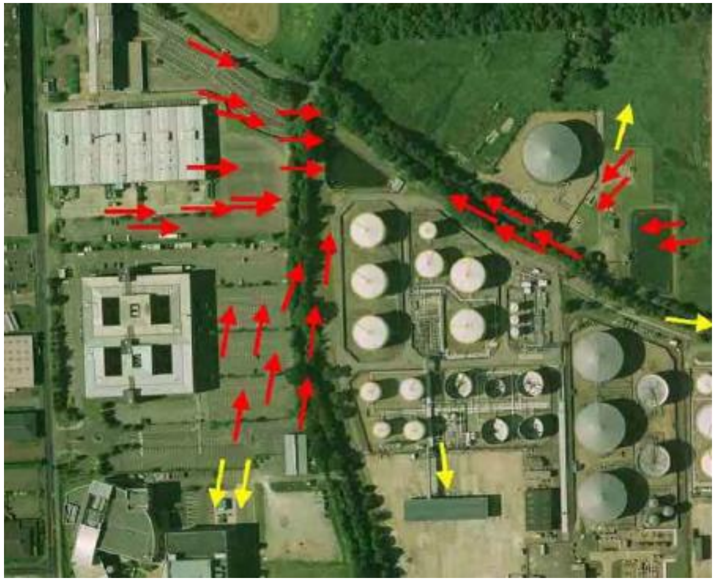
Directional Indicators

- Consistently point towards location of DDT



Buncefield

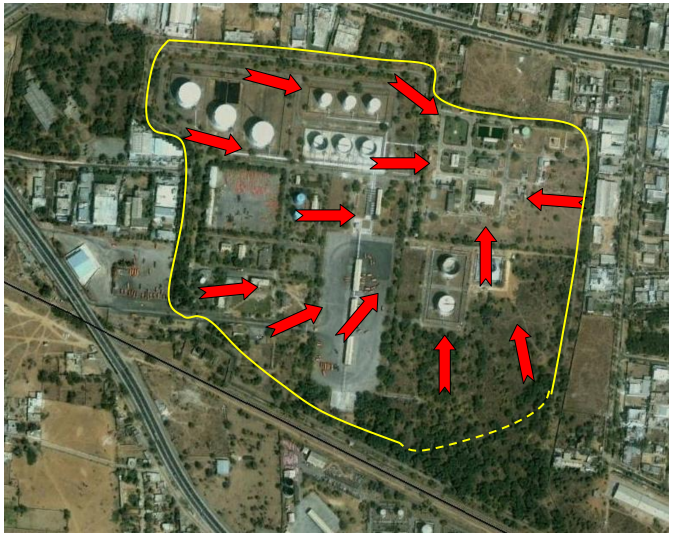
(red inside the cloud, yellow outside)

Similar directional indicators can be caused by fast deflagration

Critically, only a detonation can do this in an open area

May not be seen if cloud hemispherical – relies on reverse flow of combustion products

Jaipur



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Experimental Studies

- Detonation tests - Spadeadam
  - Propane air cloud detonation initiated by small explosive charge
  - Shock loading
- Explosion chamber tests - Spadeadam & HSL
  - Slower rise time
  - Longer duration

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Damage to Cars – Short Duration Shock Loadings

Outside the Cloud

Inside the Cloud

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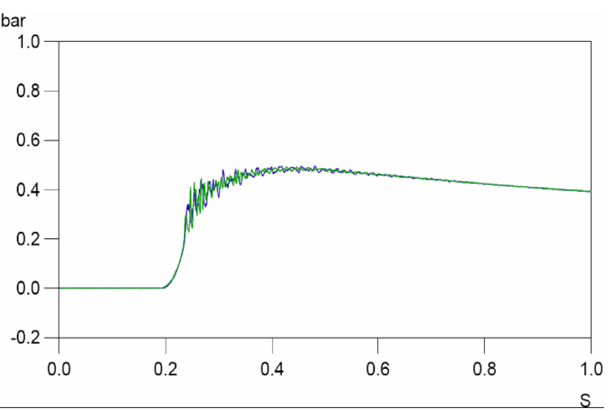
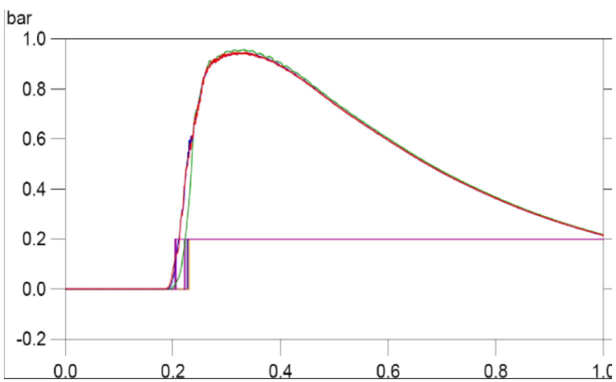
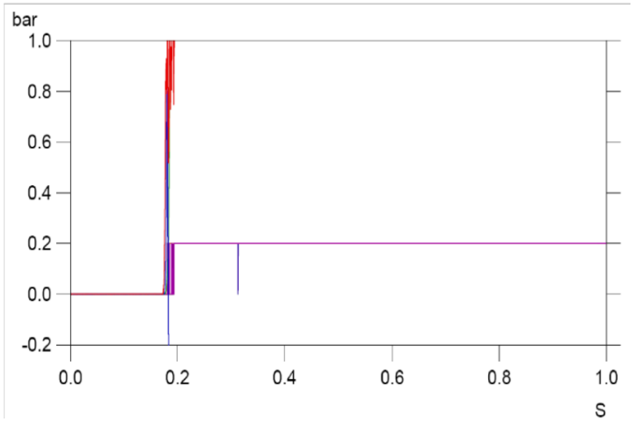
Damage to Cars – Long Duration Pressure Loadings

- Experiments carried out at Health & Safety Laboratories in an explosion chamber
- Long duration pressure loadings







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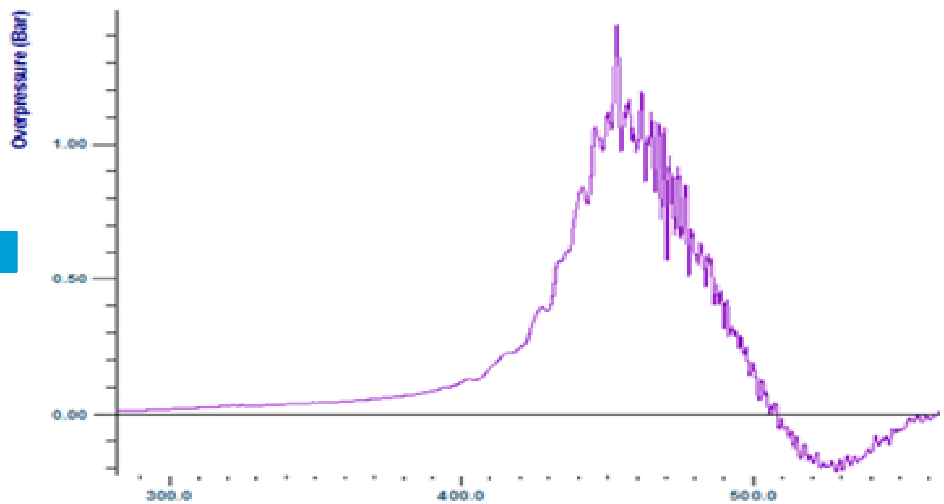
Damage to Oil Drums

Shock loading up to 4.4bar



Deflagration loading up to 1.8bar

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Damage to Oil Drums

Shock loading up to 4.4bar

Deflagration loading up to 1.8bar

Jaipur

Inside the Cloud

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Conclusions

- High pressures needed to cause the observed damage
- High speed (supersonic) deflagration could cause such damage
- When observed in the open, detonation is the only known mechanism that an result in the damage
  - This is the qualification!!
- Directional indicators will be seen in low level clouds, not hemispherical

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Other Incidents

Flixborough

Amuay, Venezuala

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Why Not DDT?

Stiochiometry

- Large scale experimental evidence relates to stoichiometric fuels
- Fuels are the most detonable

Supersonic flames needed to explain damage

- Likely to need concentrations close to stoichiometric
- Even if ignited in rich or lean mixtures, DDT will occur as soon as a 'pocket' near stoichiometric is reached

Sustained detonation

- Removes deflagration sensitivity to fuel concentration and congestion variations
- Will continue through all detonable concentrations

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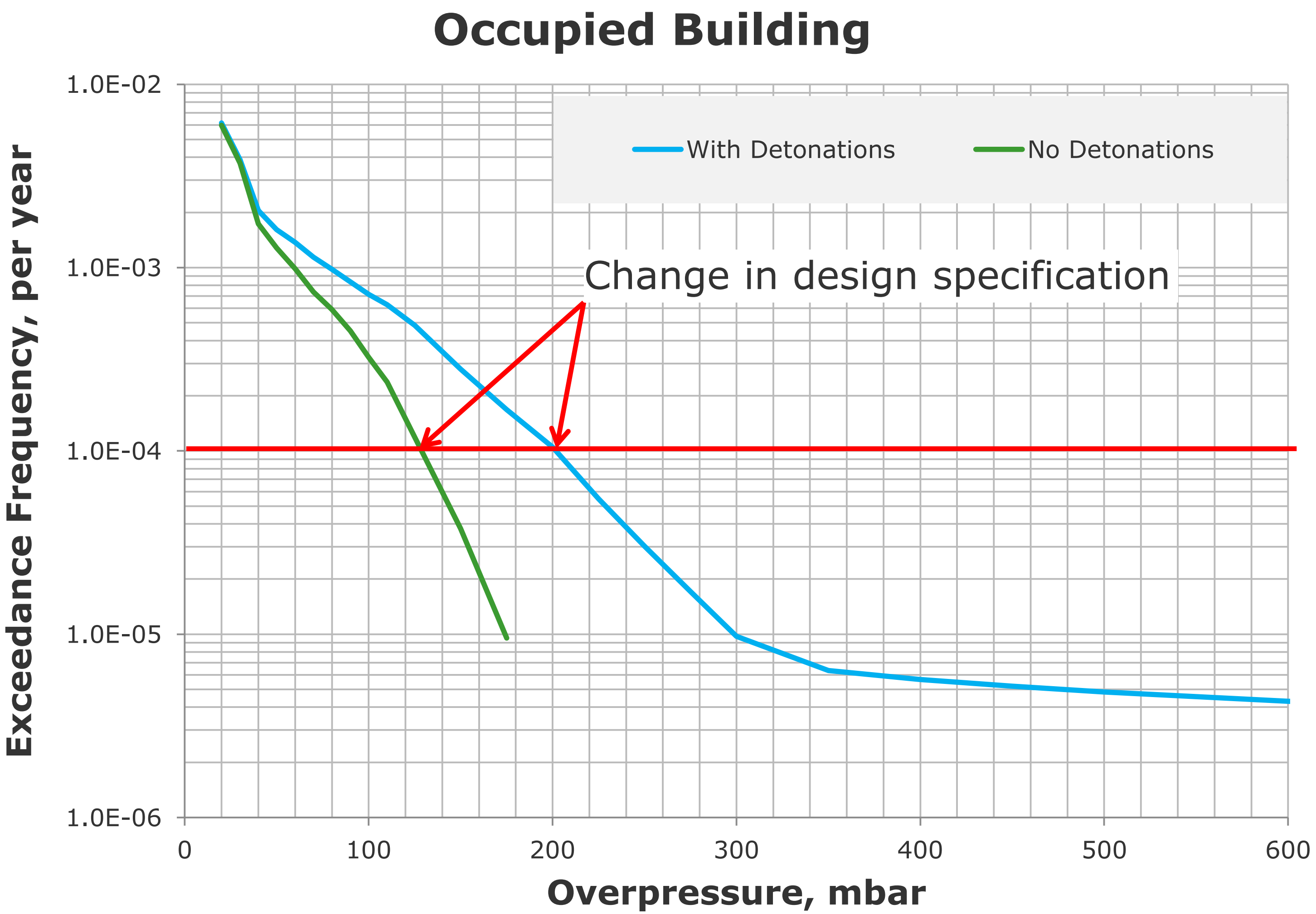
Why Does it Matter

- Current methodologies are based around congested regions
  - Not unreasonable conclusion given outcome of research into flame acceleration
- These may not properly represent the risks to personnel
- Including the potential for detonation in the assessment process, can make a difference to facility design

Risk Based Building Design



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Conclusions

- DDT has occurred in VCEs:
  - Explains widespread severe damage observed in incidents
  - Removes sensitivities deflagrations have to concentration and congestion fluctuations

- Based on experimental evidence, it is difficult to understand why many major vapour cloud explosions could not have involved DDT

- Guidance and assessment methods need to be improved to assist industry

- Guidance also needs to be provided on the interpretation of evidence from incidents

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Thank you for your attention

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