

**GL** Noble Denton



## **DDT – Why it Matters**

10<sup>th</sup> July 2013



# Overview

Some personal experience

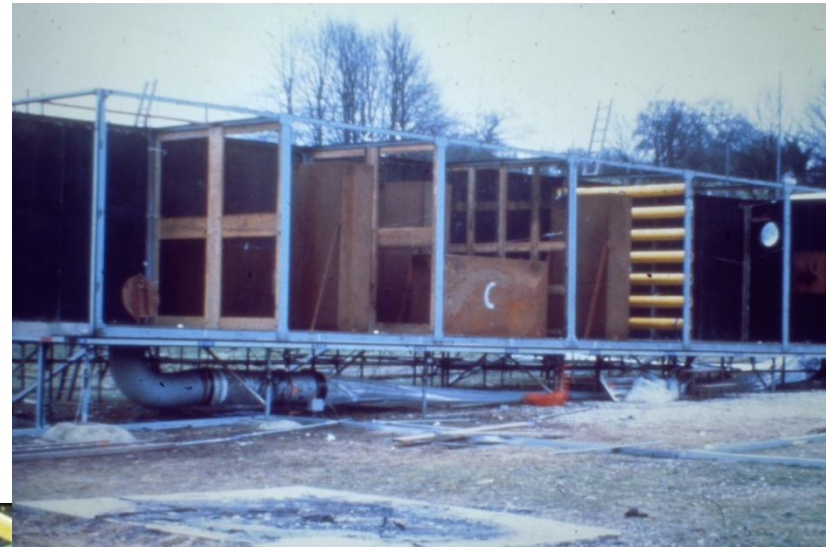
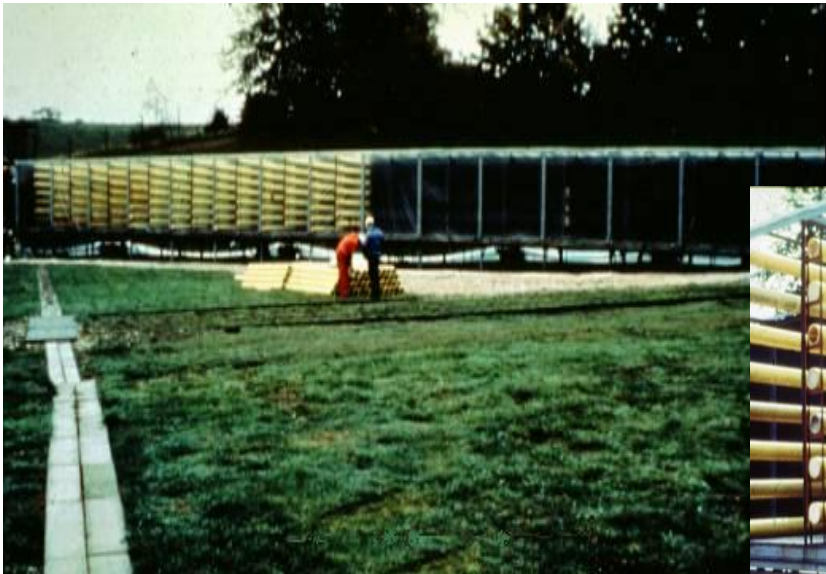
Incidents

Reasons why DDT seems likely in VCE's

Why it matters

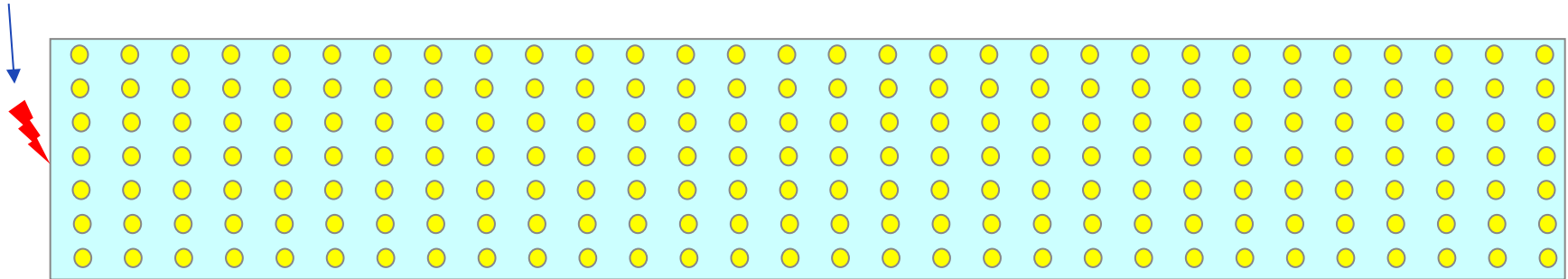
# Explosion Studies

British Gas R&D - Large scale experimental studies of vapour cloud explosions



# Experimental Arrangement

Ignition

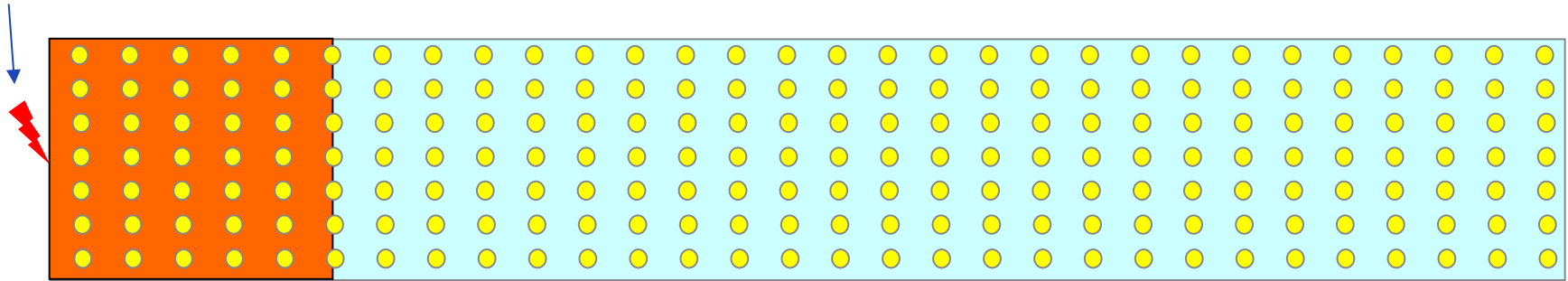






# September 1984 – Adding Initial Confinement

Ignition





# Damage

Test rig damaged well beyond repair





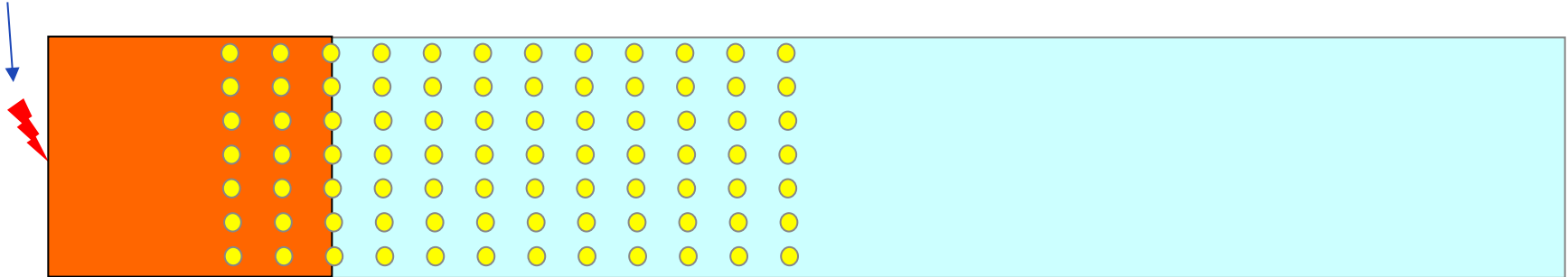
## Other Fuels

Most of the experiments up to this point had been with natural gas

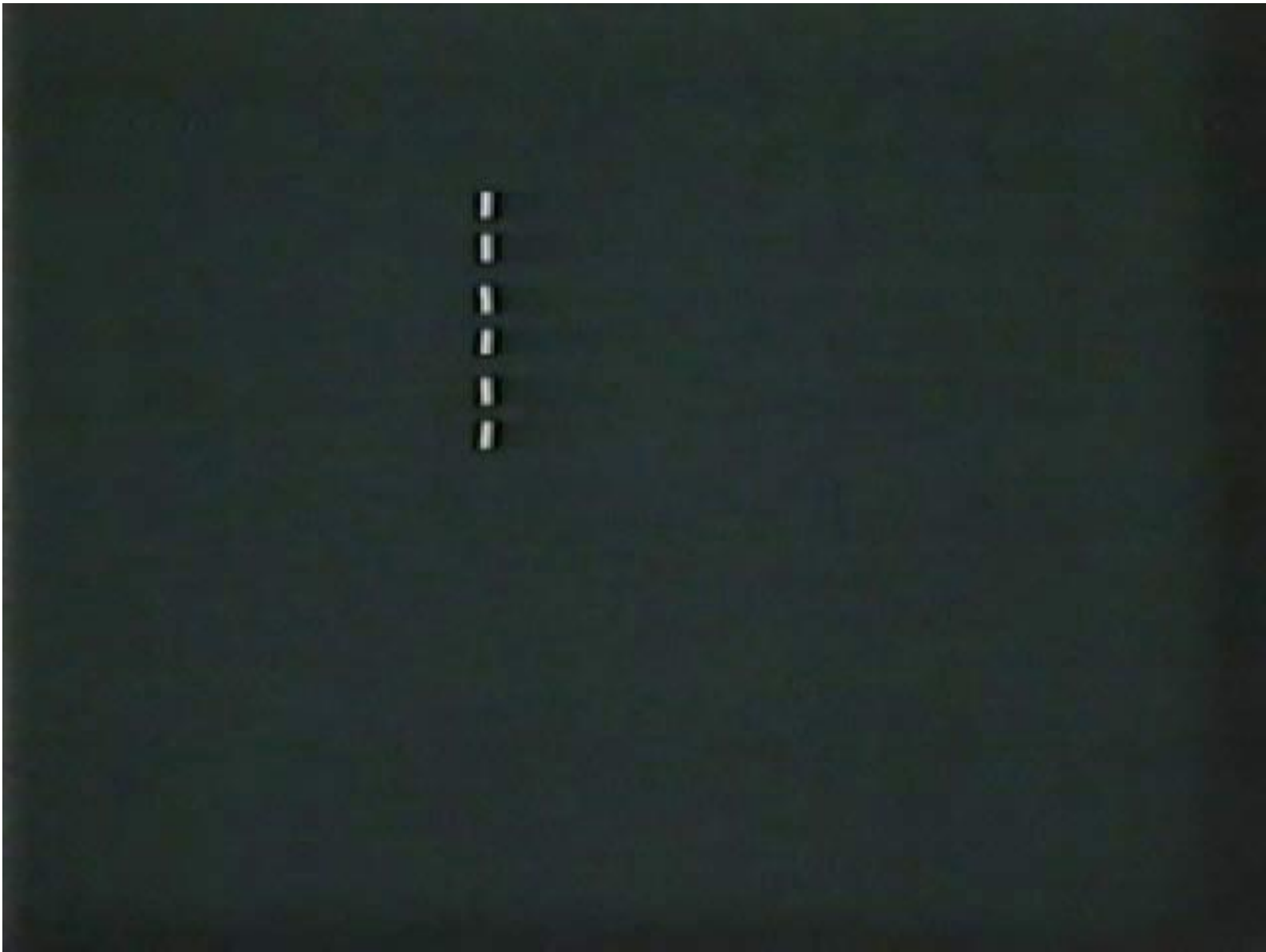
Despite very high flame speeds (supersonic) no DDT

Moved on to look at cyclohexane and propane

## Ignition







# Transition from Deflagration to Detonation (DDT)

Transition occurred when  
flame speeds were above  
ambient speed of sound

Generates shock waves  
which are sufficient to  
initiate a detonation

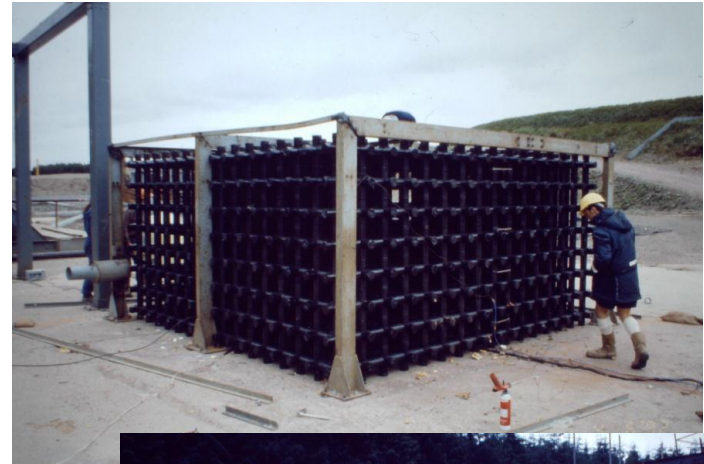
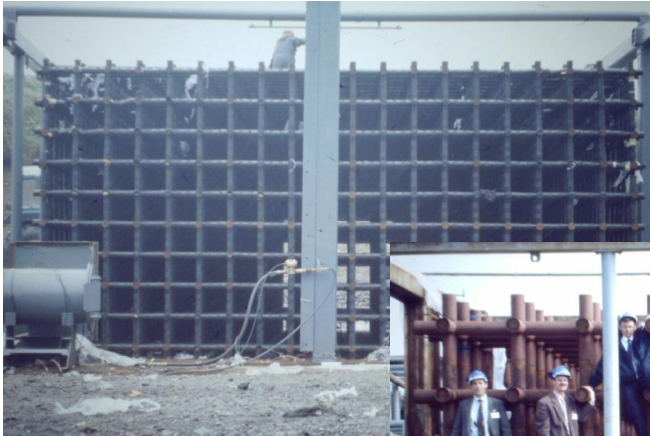
Was this a one off?



# Projects MERGE & EMERGE – Medium and Large Scale

Experiments at with various obstacle arrays

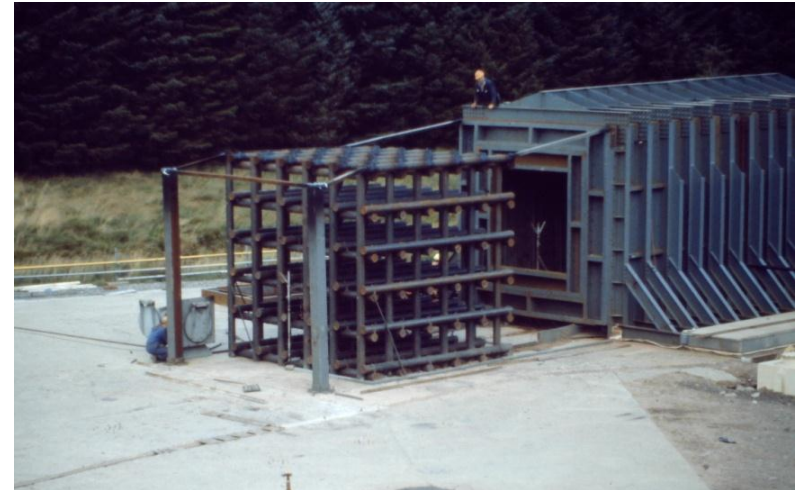
Evidence of DDT with ethylene at medium scale and propane at large scale



# Venting of Confined Explosion into Congestion

Venting of confined explosion into external congestion

Experiments with Natural Gas, Propane and Ethylene



# Venting of Confined Explosion into Congestion

With Ethylene and  
Propane, high flame  
speeds and  
overpressures produced  
Again clear evidence of  
DDT



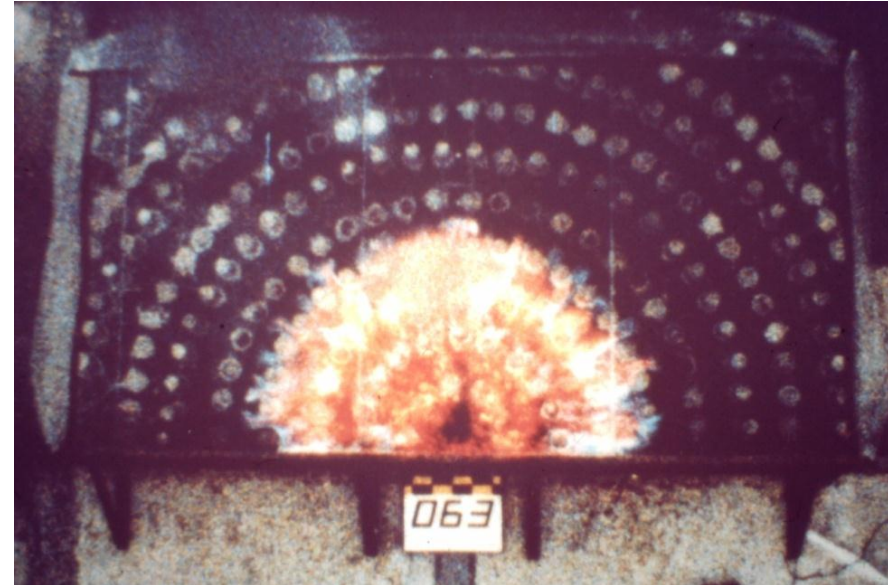




# Flame Acceleration with Ethylene

Flame acceleration through concentric rings of pipework obstacles covered by roof

Conducted with Ethylene-air mixtures



# Flame Acceleration with Ethylene

Flame acceleration through concentric rings of pipework obstacles covered by roof

Conducted with Ethylene-air mixtures

DDT occurred



# Realistic Pipework Regions

Realistic pipework congestion – one fifth linear scale

Oxygen enriched natural gas-air mixture



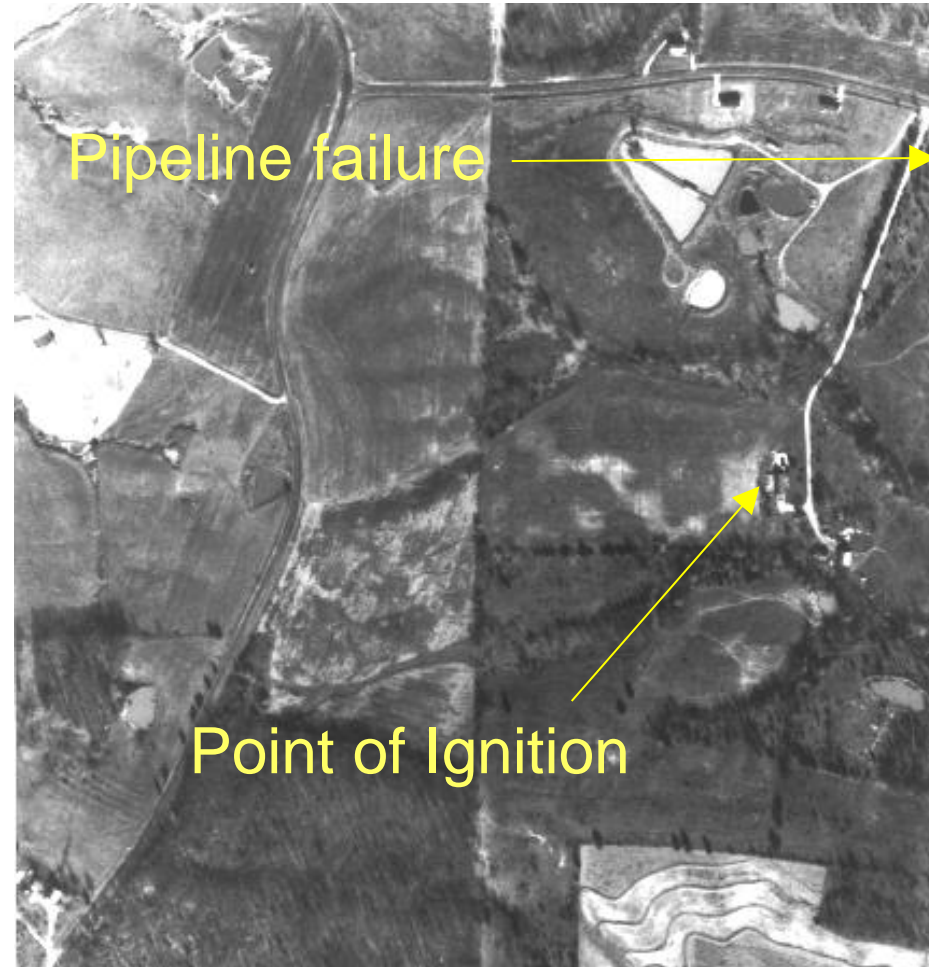




# Port Hudson Incident

Port Hudson, Missouri, 9<sup>th</sup> December 1970

- Propane pipeline failure in rural area
- Calm conditions
- Cloud dispersed through a valley ignited and exploded
- Investigation concluded it was due to detonation of the cloud



# Detonations

Severe pressure damage throughout cloud

Investigators stated:

*“We think that it is significant that the wind direction was everywhere opposite to the postulated direction of the detonation”*



## Buncefield



Evidence of widespread severe blast damage within the vapour cloud



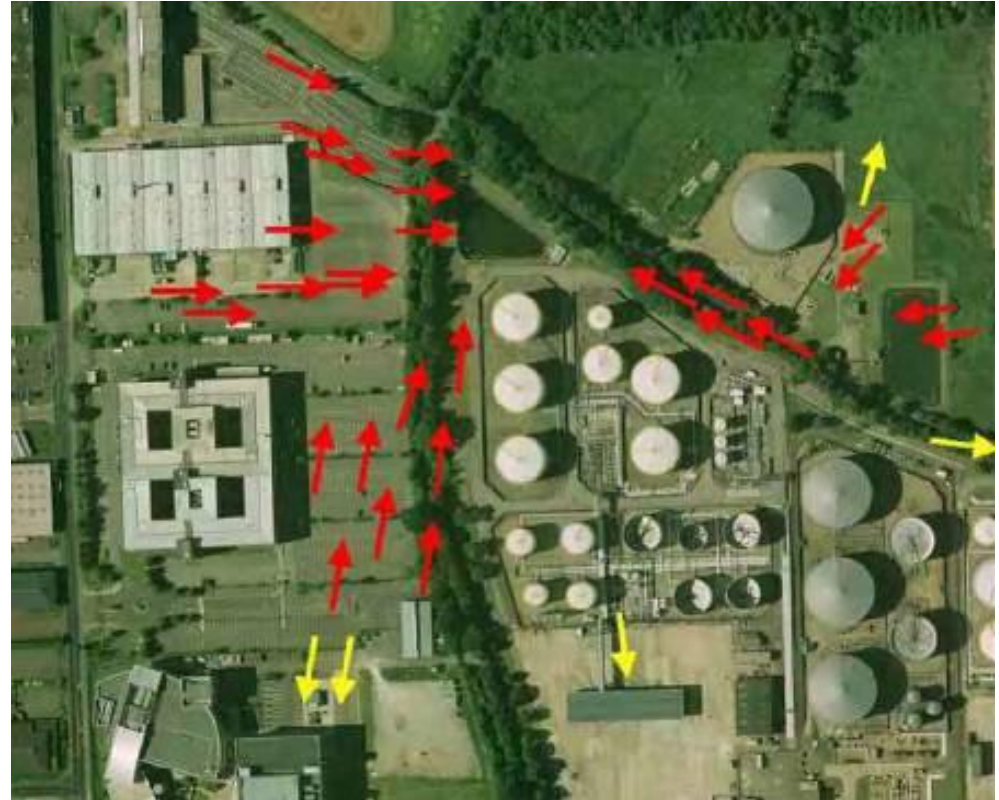


## Directional Indicators

Reverse flow behind a detonation explains why these are seen throughout the cloud

Point to location of transition to detonation

Recent experiments have confirmed that dense trees and bushes can result in DDT



## Ufa, Russia, 1989

Propane pipeline failure

Trees throughout cloud were levelled and pointing towards explosion source

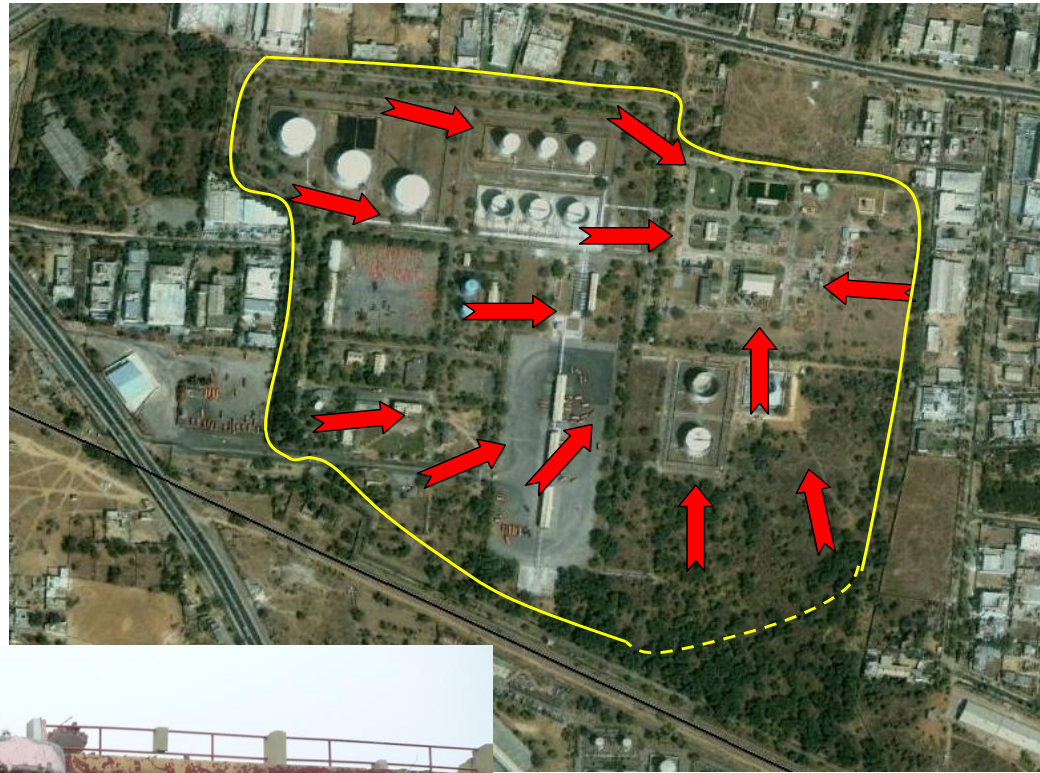




## Jaipur, India 2009

Vapour cloud covered about 3 times the area of the Buncefield cloud

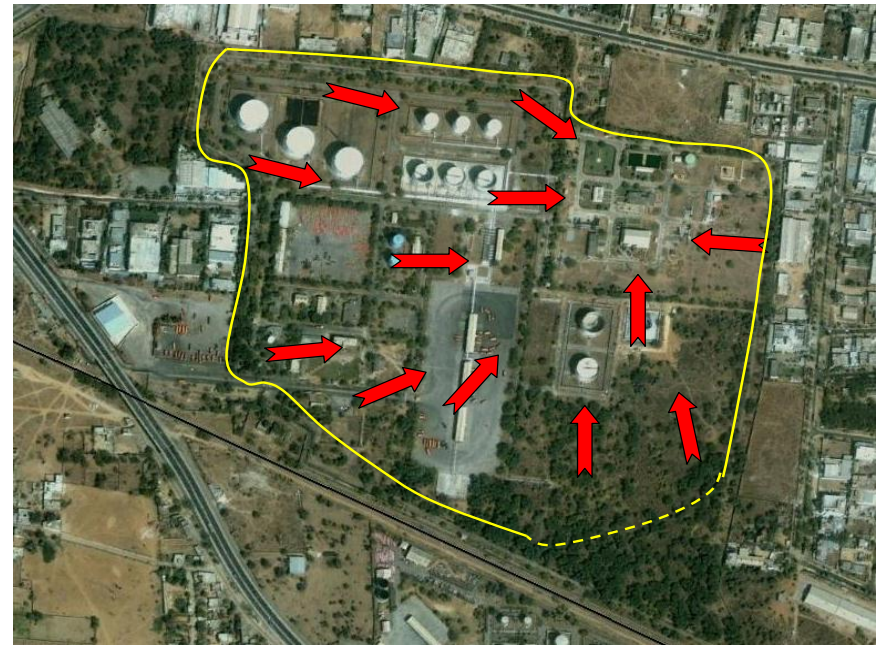
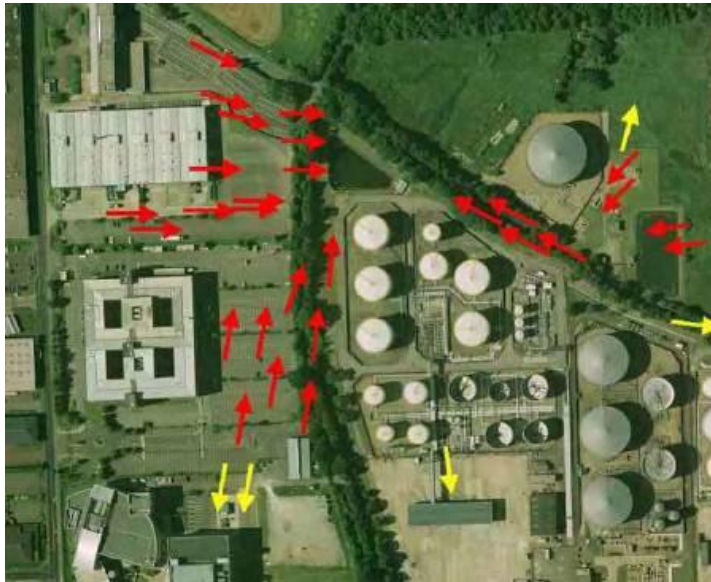
Widespread severe pressure damage in cloud plus directional



## Case for DDT

Were the directional effects due to the rising fireball after the explosion?

In Buncefield, Jaipur and most likely the Port Hudson, the 'centre' of the directional indicators was towards and edge or corner of the cloud which does not appear consistent with the fireball explanation



## Case for DDT

Other than for natural gas (?), flame speeds in excess of the ambient speed of sound lead to DDT

- Continued propagation of the detonation if flammable cloud available

High flame speeds more likely near stoichiometric, where fuel is most detonable

Detonation is less sensitive to changes in fuel concentration than a deflagration

Detonation is not sensitive to changes in the degree of congestion



## Case for DDT

Witness statements from VCE's often describe a 'flash' or sudden event

- Given the scale of the vapour clouds this implies high (super sonic) flame speeds which most likely will lead to detonation

Detonation explains the severe pressure damage (several bar at least) throughout the cloud

- Not explained by decaying pressure wave from single or multiple deflagrations

## So What?

Immediate and practical

- For on-site design, a risk based approach would generally exclude detonation events
- Situation can be different for offsite risks and can be important for land use planning

But there are wider issues

- A key element in the management of major hazards is making people aware and vulnerable
- We need to guard against being drawn towards the ‘credible’ and not encompassing the full range of possibilities

**GL** Noble Denton



**Thank you**

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