Fire Safety in Oil Storage Installations

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Introduction

- Fire Safety in Bulk Flammable Stores:
  - Risks of major accidents
  - Measures to protect against major accidents
  - Design and operation of a petroleum storage installation
  - Fire fighting policy / emergency response planning
- Case studies:
  - Dublin Port
  - Sullom Voe
  - Buncefield

Concept of Risk

- Hazard
  - Intrinsic property of a dangerous substance or physical situation
- Consequence
  - The outcome of an event as a loss, injury, disadvantage or gain
- Probability
  - The likelihood of a specific event or outcome
- Risk
  - A combination of Probability and Consequence

Hazard Identification and Risk Assessment

- Formal assessment of all foreseeable major accident scenarios.
  - Loss to aquatic environment
  - Fire
  - Explosions
- Assess Severity and Likelihood of each scenario → Risk.
- Thresholds for assessing the levels of Risk.
- Additional improvements where necessary.

Matrix used for Risk Assessment

	Severity of Consequences					
Likelihood of Occurrence	**0 Negligible**	**1 Minor**	**2 Appreciable**	**3 Severe**	**4 Very Severe**	**5 Catastrophic**
1 Virtually Impossible	0 Trivial Risk	1 Trivial Risk	2 Trivial Risk	3 Trivial Risk	4 Trivial Risk	5 Minor Risk
2 Improbable	0 Trivial Risk	2 Trivial Risk	4 Trivial Risk	6 Minor Risk	8 Minor Risk	10 Moderate Risk
3 Unlikely	0 Trivial Risk	3 Trivial Risk	6 Minor Risk	9 Moderate Risk	12 Substantial Risk	**15 Priority Risk**
4 Infrequent	0 Trivial Risk	4 Trivial Risk	8 Minor Risk	12 Substantial Risk	**16 Priority Risk**	**20 Priority Risk**
5 Occasional	0 Trivial Risk	5 Minor Risk	10 Moderate Risk	**15 Priority Risk**	**20 Priority Risk**	**25 Priority Risk**
6 Frequent	0 Trivial Risk	6 Minor Risk	12 Substantial Risk	**18 Priority Risk**	**24 Priority Risk**	**30 Priority Risk**

Risk of Major Fire

- Use of Literature Data to calculate probabilities (TNO, HSE).
- Calculation is site-specific.
- Probability depends on number of tanks, pipelines, throughput etc as well as on the measures in place.
- A major fire is a credible scenario for any installation involved in the Bulk Storage of Flammable Materials.

Risk of Major Explosion

- Risk of an explosion is not so well established.
- Not previously considered credible for spills of Flammable Liquid.
- Buncefield showed that it could happen.
- Circumstances of Buncefield Incident still under investigation.
- Authorities will advise on the risk of this event.

Impacts of Major Fires

- High Heat Fluxes to other tanks and equipment.
- Risk to personnel in vicinity of the fire.
- Impact depends on the scale of the fire:
  - Tank Fire
  - Bund Fire
  - Fire resulting from Catastrophic Tank Failure

Examples of Tank Fires

Example of a Bund Fire

Example of Catastrophic Failure

Example of Catastrophic Failure

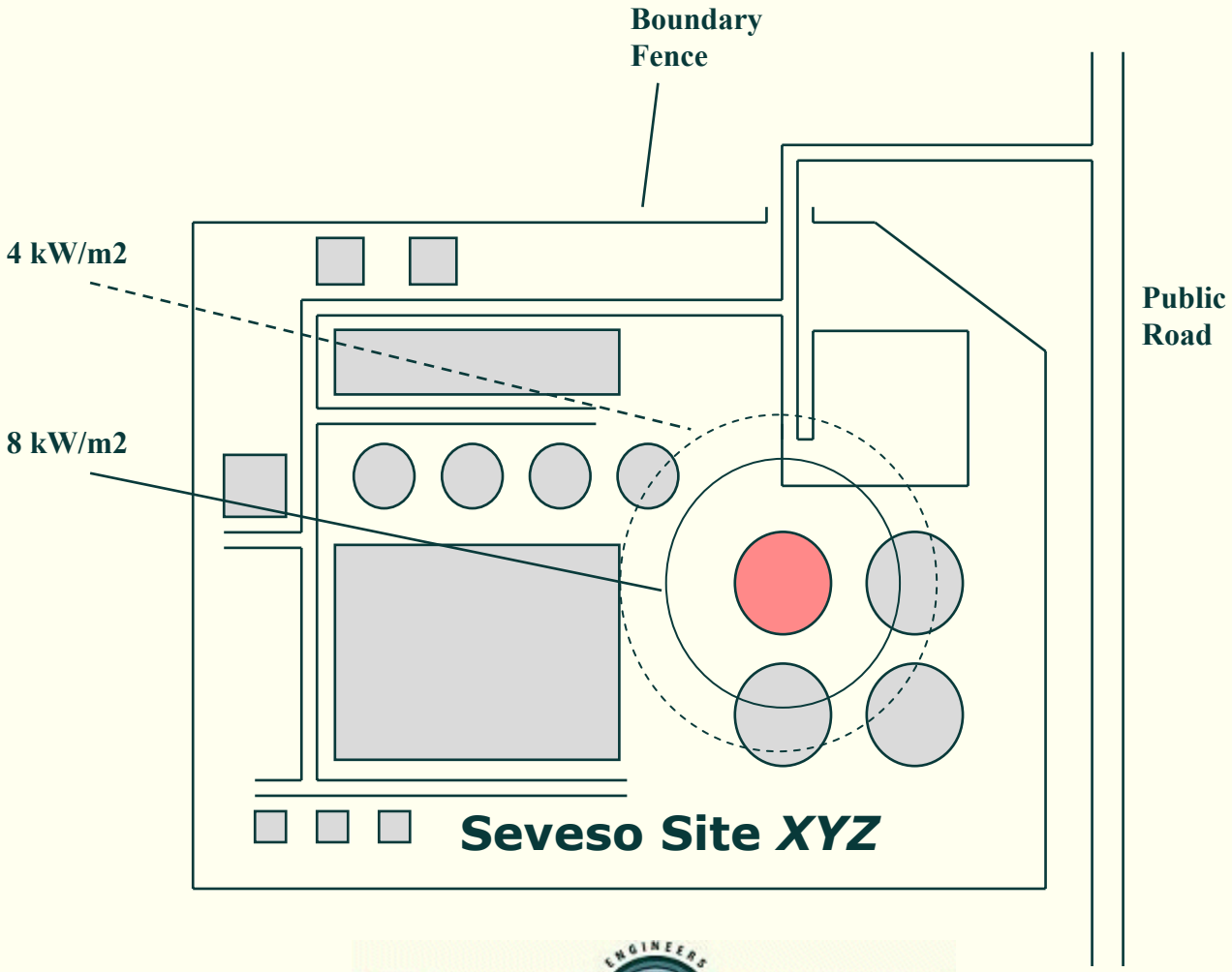
Consequence Modelling of Fires

- Software Packages or literature data.
- Impact of fire depends on a number of parameters:
  - Surface area of fire
  - Product involved
  - Wind speed
  - Distance to receptor
- Model plots heat flux against distance.

Consequence Modelling of Fires – Endpoints

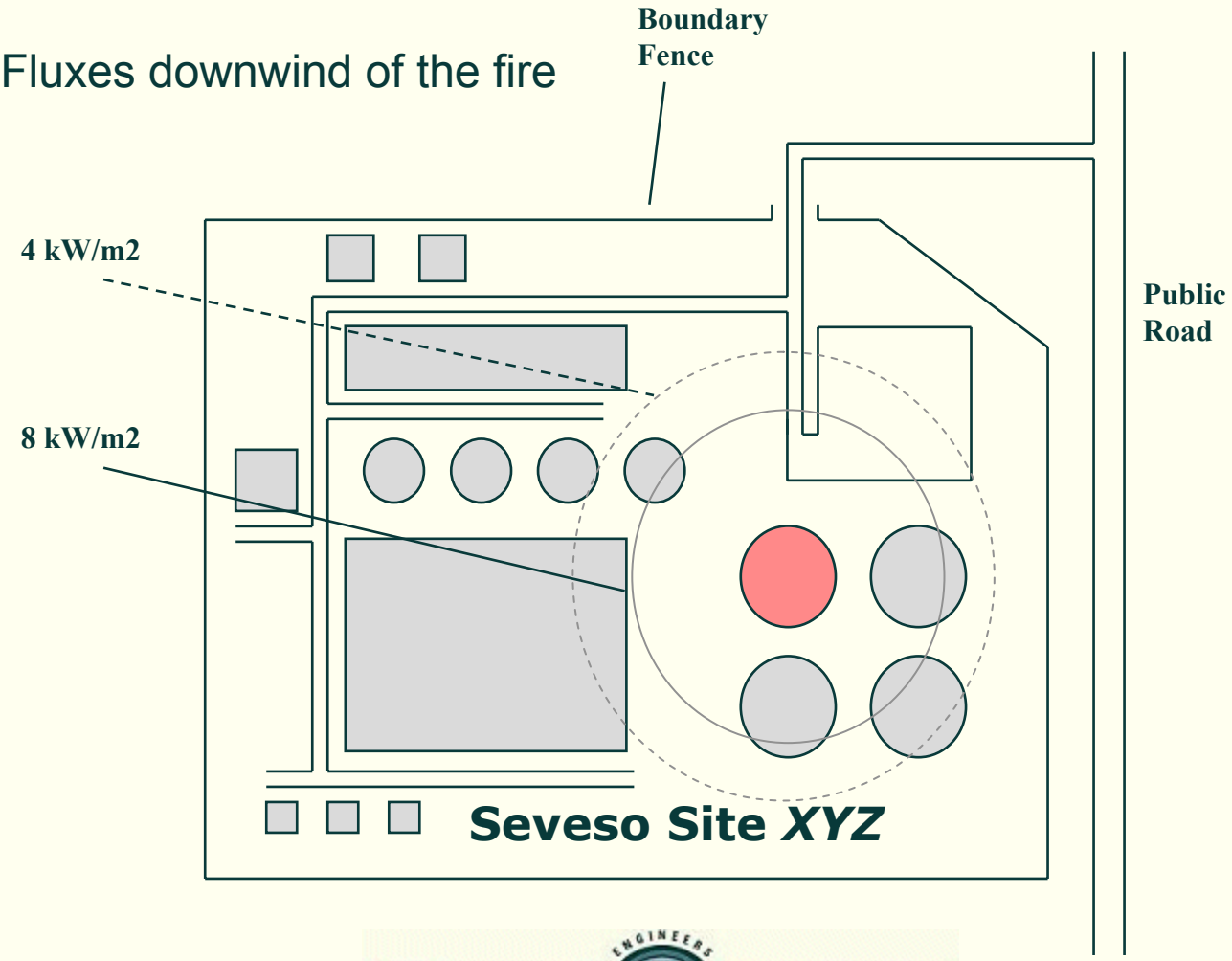
- Heat Radiation Levels (kW/m^2):
  - 4 kW/m^2: Specified Area. Safe access for fire fighters.
  - 6.3 kW/m^2: Maximum safe level at an emergency exit.
  - 8 kW/m^2: Threshold level for protective cooling.
- Thermal Dose Levels $((kW/m^2)^{4/3}.s)$:
  - 500 TDU: Threshold of fatality
  - 1000 TDU: 1% fatality
  - 1800 TDU: 50% fatality

Consequence Modelling – calm weather

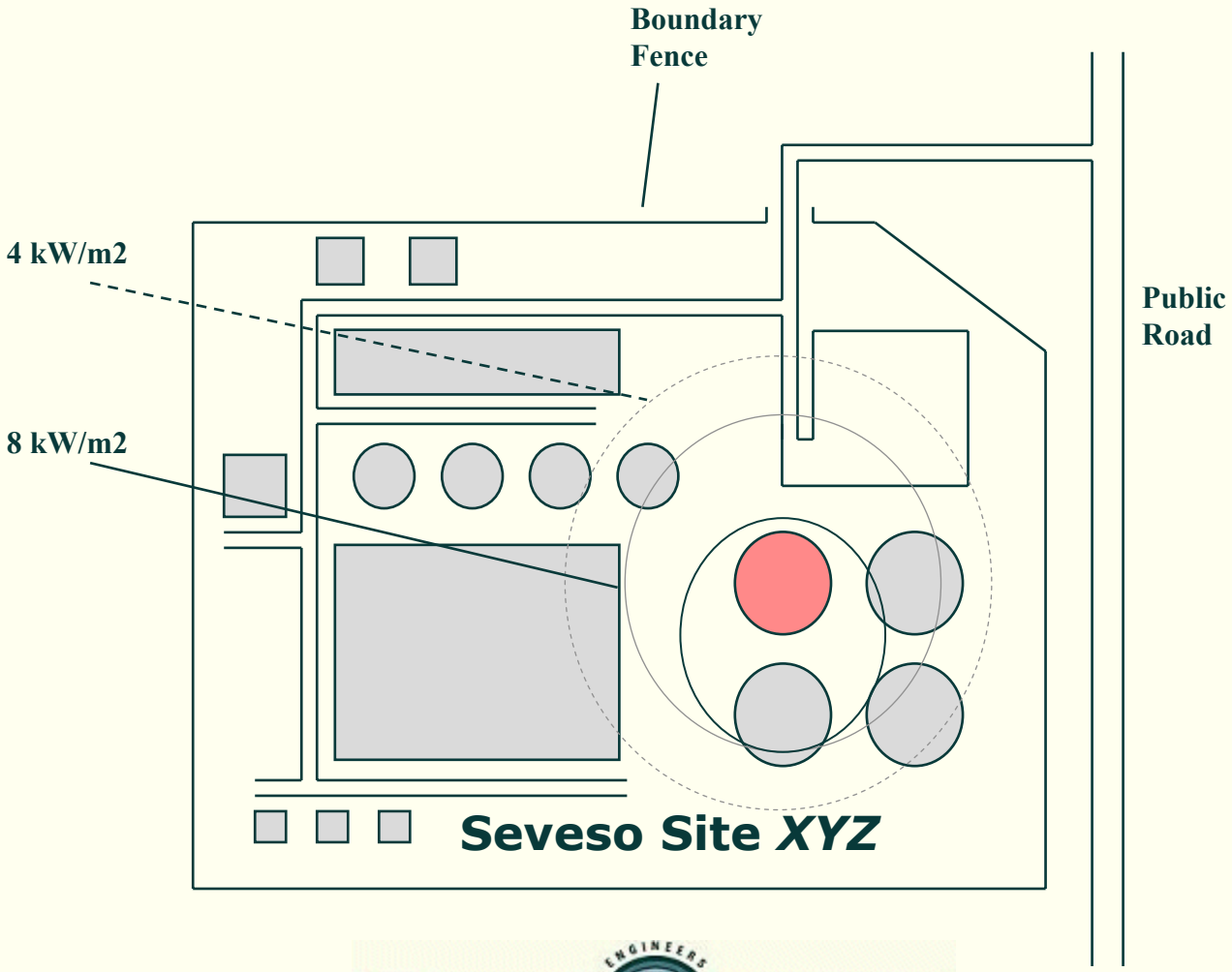


Consequence Modelling – flame tilt

Heat Fluxes downwind of the fire



Consequence Modelling – flame tilt



Impacts of Major Explosions

- Overpressure levels:
  - 30 mbar: Specified Area. Limited minor structural damage
  - 70 mbar: Damage to roof of storage tank
  - 150 mbar: Partial collapse of walls and roofs of houses
  - 1000 mbar: Collapse of supporting structure of round storage tank
- Not straightforward to model explosion of flammable liquid.
- Buncefield Investigation.

Measures to Protect against Fires / Explosions

- Measures to prevent loss of containment:
  - Level Indicator with independent High Level Alarm
  - Maintenance inspections
  - Impact protection
- Measures to reduce risk of ignition:
  - Hazardous Area Zoning
  - Electrical equipment to be in compliance with ATEX
  - Permit-to-work system in hazardous areas

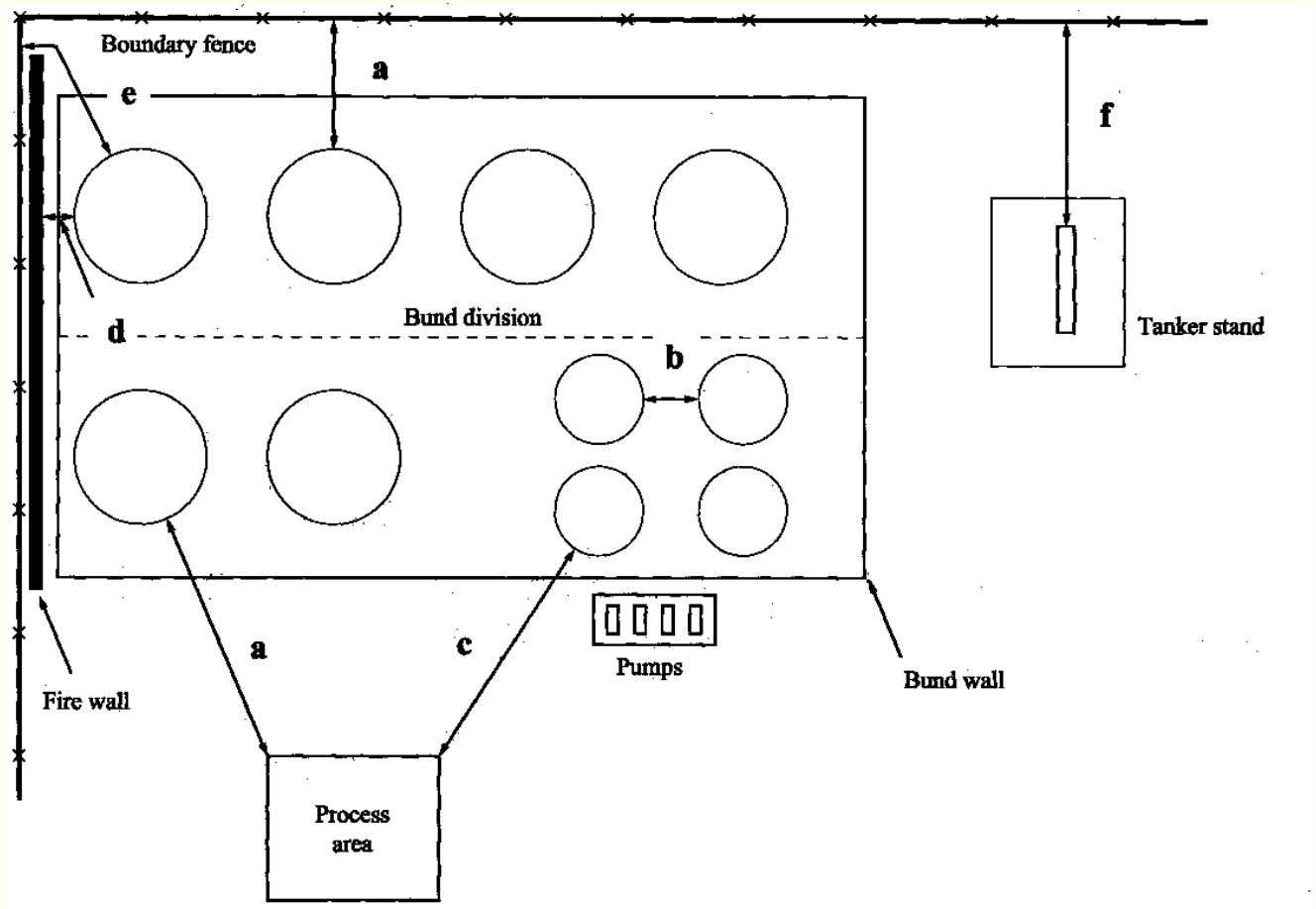
Measures to Protect against Fires / Explosions

- Measures to reduce the impact of a fire:
  - Tank Spacing
  - Bund Design
  - Fire Fighting Plan
  - On Site and Off Site Resources
  - Site location (for new facilities)

Design of Petroleum Storage Installations

- Bulk Storage Regulations, 1979.
- New sites must also take account of codes and standards, e.g. IP and NFPA Codes.
  - Tank Spacing
  - Bund Capacity (110% rule, max inventory per bund)
  - Distances to boundaries and non-process equipment
- Existing sites may not be able to comply fully with new Codes.

Sample Site Layout (from HSG 176)



Developing a Fire Fighting Policy

- Examine the fire scenarios that can arise:
  - Tank Fire
  - Bund Fire
  - Catastrophic failure
  - others
- Calculate the water and foam requirements (IP 19, NFPA):
  - Foam application to fire
  - Water to engulfed tanks
  - Water to adjacent tanks

Developing a Fire Fighting Policy

- Compare requirements with the available resources:
  - Flow rates, pressures in mains
  - Foam stocks
  - Ability of system to apply resources where needed
- Maximum Feasible Extinguishment:
  - Fight a scenario with fixed or semi-fixed equipment
  - Fight a scenario with mobile equipment
  - Pump product out, let tank burn and protect adjacent tanks
- Upgrade facilities where necessary.

Case Study – Fire Fighting Study at Dublin Port

- Survey of 15 sites.
- Large inventory of hazardous substances:
  - 9,000 m^3 LPG
  - 115,000 m^3 Gasoline and Kerosene
  - 154,000 m^3 Gas Oil / DERV / HFO (Class III(2))
- Project to review fire scenarios and response options.
- Recommend appropriate strategy for medium to long term.

Aerial Picture of Dublin Port

Scope of Project

- Review existing arrangements against best practice.
- Assess potential worst case fire scenarios at each location (15 sites, COP, Jetties and truck/rail movement).
- Assess capacity of existing facilities to cope with the credible scenarios.

Scenarios Examined

- Flash fire or explosion involving LPG:
  - Event would be over before response could be mounted
  - Aftermath likely to be similar to catastrophic tank failure
- Fire involving flammable liquid storage:
  - Full roof fire in a single tank
  - Full bund fire, possibly involving several tanks (including Class III)
  - Catastrophic tank failure with ignition
- Other scenarios.

Methodology

- Modelling of major fire scenarios.
- Assessment of resources required to attack these scenarios.
- Determined current capabilities at the Port.
- Comparison of recommended requirements with capabilities:
  - Water supply and foam stocks
  - Ability of on-site & DFB systems to apply water and/or foam
- Develop Policy.
- Make recommendations on Fire Protection System.

Results

- Tank Fires:
  - Sufficient foam and water supply in place, in theory
  - Not easy to apply for tanks without fixed drenching systems
  - Foam storage arrangements unsuitable for a large monitor
- Bund Fires / Catastrophic Tank Failure:
  - Insufficient foam and water resources in place to extinguish

Catastrophic Failure with Running Pool Fire

- Fire covering a large area
- Impractical to provide the level of foam and water required:
  - Water required at nearly 4 tonnes/second
  - Fire main would need to be greater than 1 m diameter
  - Eight tankers, each holding 30 m^3 foam, required on standby
- Access to mount attack impossible, even if equipment available.
- Not reasonable to extinguish – plan to prevent escalation.

Two Policy Options

- Deal with All Tank Fires:
  - Fixed foam systems on Class I & II tanks
  - Drencher systems on Class I & II and some Class III tanks
  - Portable foam/water monitors for first response
  - Upgrades to mains system
  - One high capacity foam monitor
- Deal with all Bund Fires:
  - Two high capacity foam monitors
  - Additional foam stocks
  - New fire-water ring main (450 mm)

Case Study – Sullom Voe

- Located in the Shetland Islands, off the coast of Scotland.
- Consortium arrangement: Managed by BP.
- Capacity c.1.4 million m^3 crude.
  - Crude: 16 tanks
  - LPG: 4 spheres
- Terminal throughput of c.800 thousand bpd.

Site Layout

Arrangements at Sullom Voe

- Dedicated Emergency Response Group in place.
- Recent review of Fire Fighting Policy.
- Upgrades to Fire Fighting Systems to extinguish full roof fires:
  - Risk of boil over in crude tanks
  - Importance of facility
- Also decided to reduce inventory levels in propane tank.

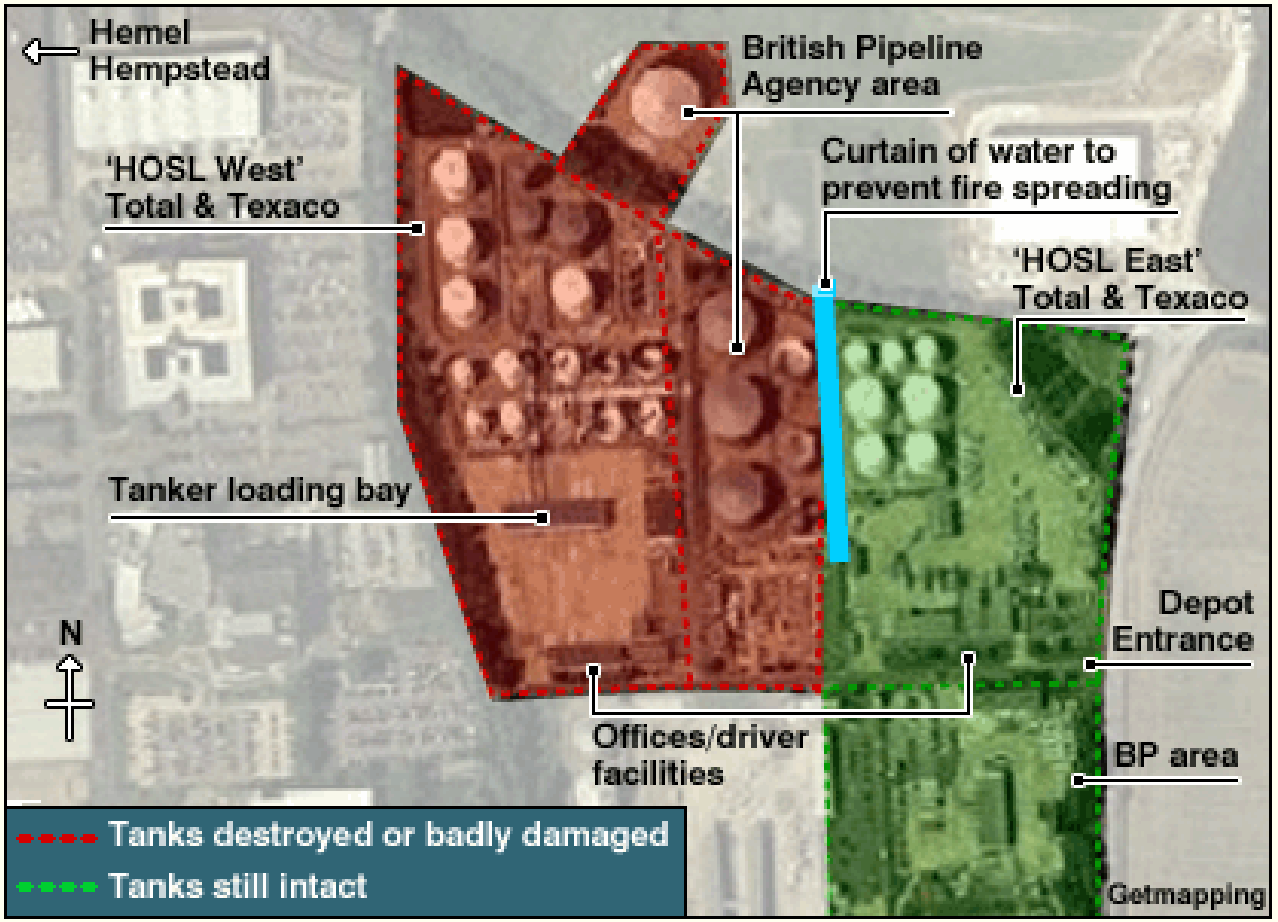
Case Study – Buncefield Incident

- Depot stored Gasoline, Kerosene, Diesel and other fuels.
- Site capacity of c.275 million litres.
- Critical point on UK Oil Pipeline network.
- Throughput – 8% of UK oil, 40% of aviation fuel to Heathrow.

Description of Event

- Overfilling of Gasoline tank:
  - Delivery commenced at c. 19:00 on 10th December 2005
  - Level gauge unchanged from 3:00 although delivery continued
  - Product overfill commenced about 5:20
  - First explosion at 6:01, followed by further explosions
- Resulting fire engulfed 22 storage tanks.
- Low number of injuries, no fatalities.

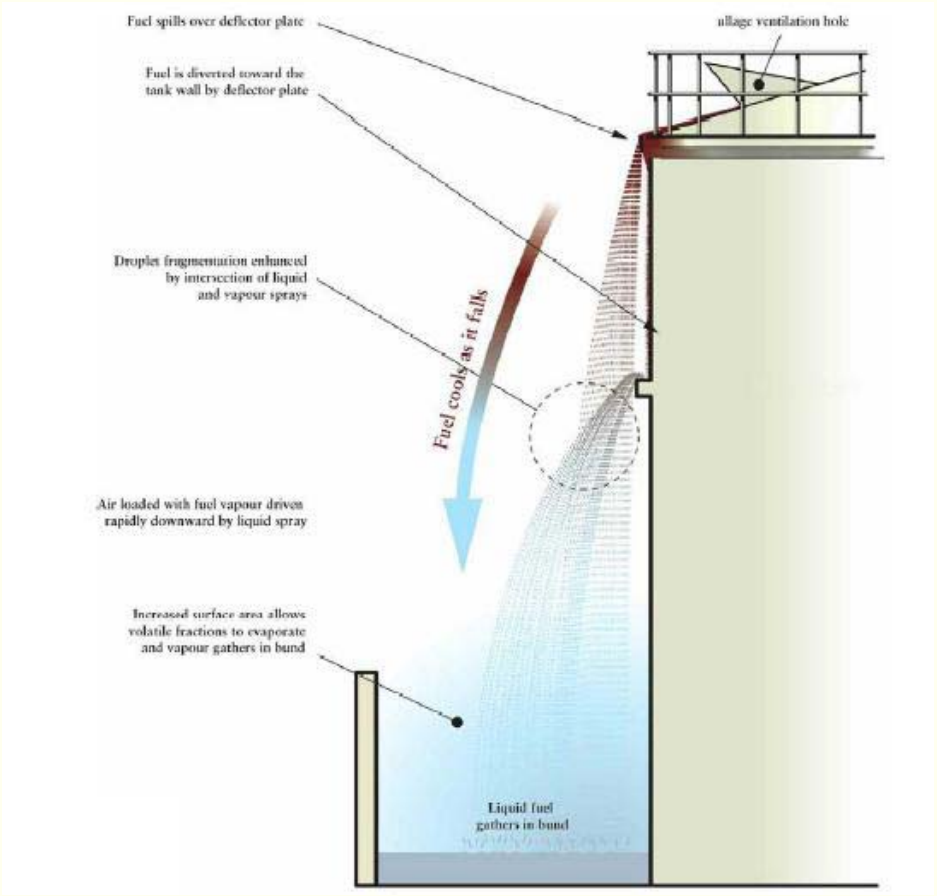
Buncefield Site Layout



Description of Event

- Free fall of product promoted formation of rich fuel/air mixture:
  - Some product flowed over deflector plate
  - Much of the deflected product hit a wind girder
- Fuel/air mist was heavier than air.
- Several ignition sources.
- Overpressures much higher than would have been predicted:
  - Damage to nearby car park suggests 700 – 1000 mbar
  - Expected overpressures would be 20 – 50 mbar

Pattern of Fuel Dispersion



Hazards Associated with the Fire

Hazards Associated with Smoke

Fire Fighting Response

- Response provided by Herfordshire plus 31 other Fire Brigades.
- Over 700,000 litres of foam concentrate used.
- 68 million litres of water used.
- Dynamic response:
  - Environmental considerations (containment of run off)
  - Change of wind direction
  - Re-ignition of tanks / bunds
  - Problems with water and foam supplies

Containment of Run Off

- Some loss of containment from bunds.
- Following event, contaminated firewater removed from the site.
- Further removal of contaminated water (rainfall and cleaning).
- Water moved to storage facilities pending treatment.
- Loss of 800,000 litres contaminated water from storage facility.

Safety Alerts issued by HSE

- February 2006
  - Review operations, plant, training, procedures etc
  - Ensure appropriate measures in place for loss of containment
- July 2006
  - Problem with overfill protection
  - TAV level switches tested by adjusting lever at head of switch
  - Must return to correct position and lock in place

Safety Alerts issued by HSE

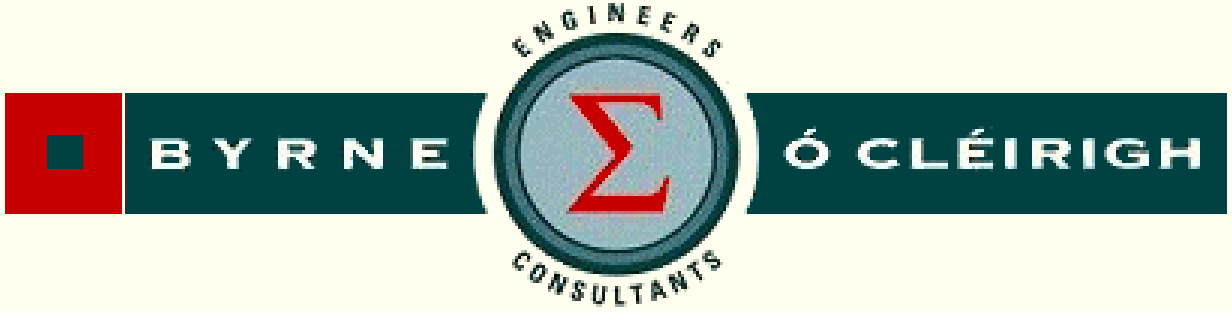
- October 2006
  - Operator checks for pipeline transfers
  - Integrity and independence of controls for tank filling
  - Fire Safe Shut-Off Valves close to tank on inlet and outlet
  - Remotely Operated Shut Off Valves should fail safe
  - Joints in bunds must be capable of resisting fire
  - Tertiary containment measures to prevent uncontrolled escape of firewater and other products
  - Effective shift/crew handover communication

Hertfordshire Fire and Rescue Service Report

- Launched just last week (8th November).
- Step-by-step examination of the incident response.
- Recommendations:
  - System to maintain accurate record of fire responders at scene
  - Consideration of type, quantity and duration of deployment of national resources
  - Earpieces to enable communication while wearing a helmet
  - National system of incident command support teams for deployment during catastrophic or protracted incidents

Summary of Findings and Recommendations

- Investigation still not completed.
- Focus of attention on preventing loss of primary containment.
- Overfilling more likely to produce explosive mixture than pooling from low level release.
- Site Layout and Location and protection of emergency facilities.
- Review of guidance on handling and storing flammable liquids.
- Review of emergency response to incidents.
- Land use planning.



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