Practical Modelling & Hazard Assessment of LPG & LNG Spills

UKELG 3rd April 2012

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Introduction

- Refrigerated or pressurised
- Release scenarios & release rate
- Vaporisation
- Gas dispersion
- Consequences
  - Jet fire / Pool fire / VCE / BLEVE
- Ignition potential
- Comparison between LPG & LNG

Hazard Identification

- Based on assessment of potential types of leak
  - Pipe sizes
  - Joints
  - Leak frequencies
- Published data
- Methodology – PRA, HAZOP, HAZID etc

Modelling

- Modelling needs to reflect an appropriate range of scenarios
- Use engineering judgement to assess potential failure modes
- Based on equipment configuration
- Location
  - Bunding, surface, congestion, confinement

Pressurised / cryogenic releases

- **Pressurised storage**
- **Ambient temperature**
- **P = ~8 barg (LPG)**
- **High release rate**
- **Jet mixing**
- **Pool possible**
- **Flashing flow (long pipes)**

- **Cryogenic storage**
- **Temperature -50°C to -100°C**
- **P = atmospheric**
- **Lower release rate**
- **Pool formed**
- **Instantaneous and long term flash**

Modelling

Gas dispersion

- Computer based models
- Statistical
- Affected by buildings etc in near field
- Ignition to LFL/2 isopleth
- Source term definition is critical
- Accuracy +/-30% at best

Key Factors

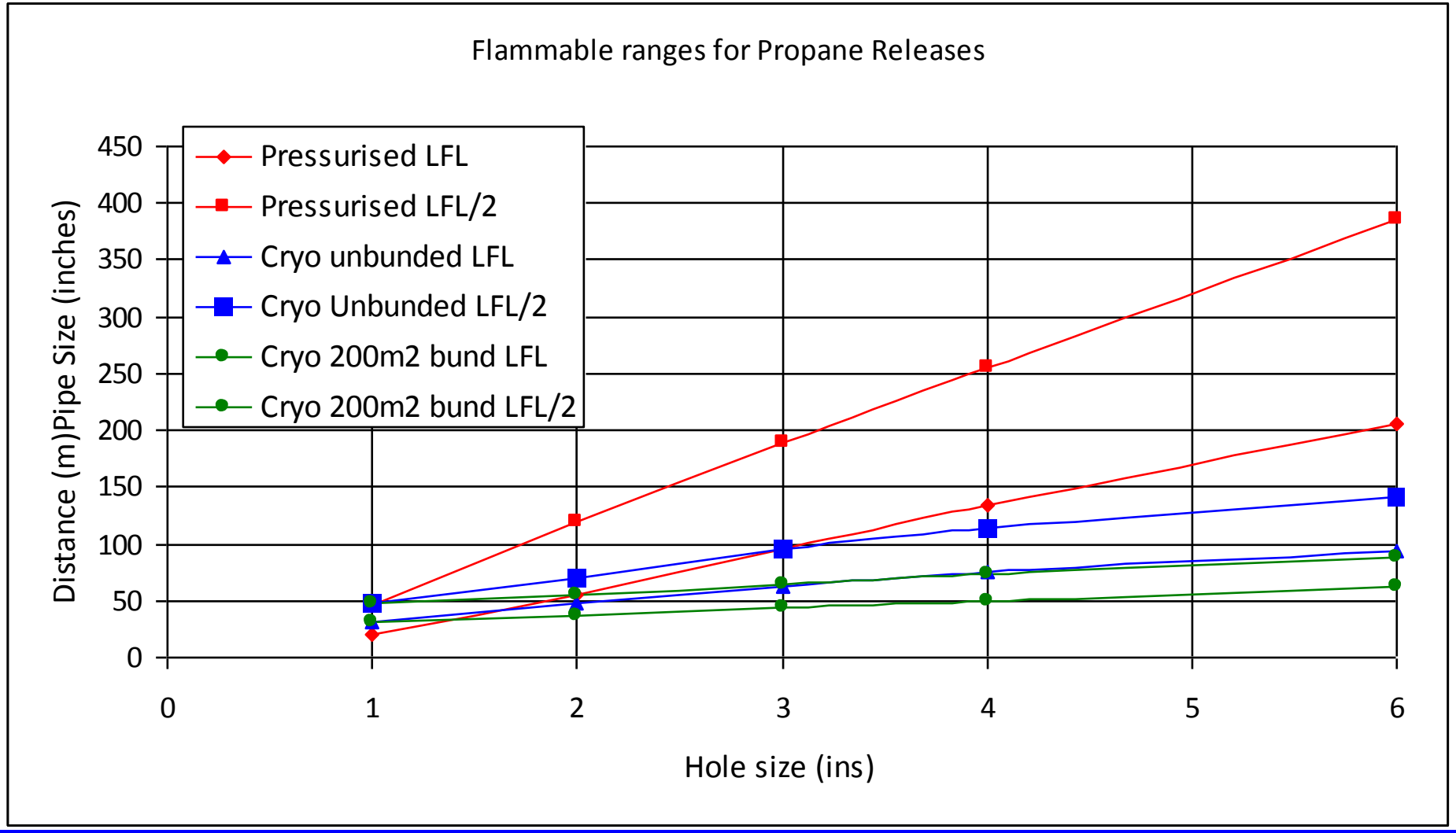
- Release rate / hole size
- Orientation
- Elevation
- Pipe length, fittings etc
- Pressure & liquid head
- Impingement
- Bund size if present
- Wind / Weather conditions

Release rate comparison (LPG)

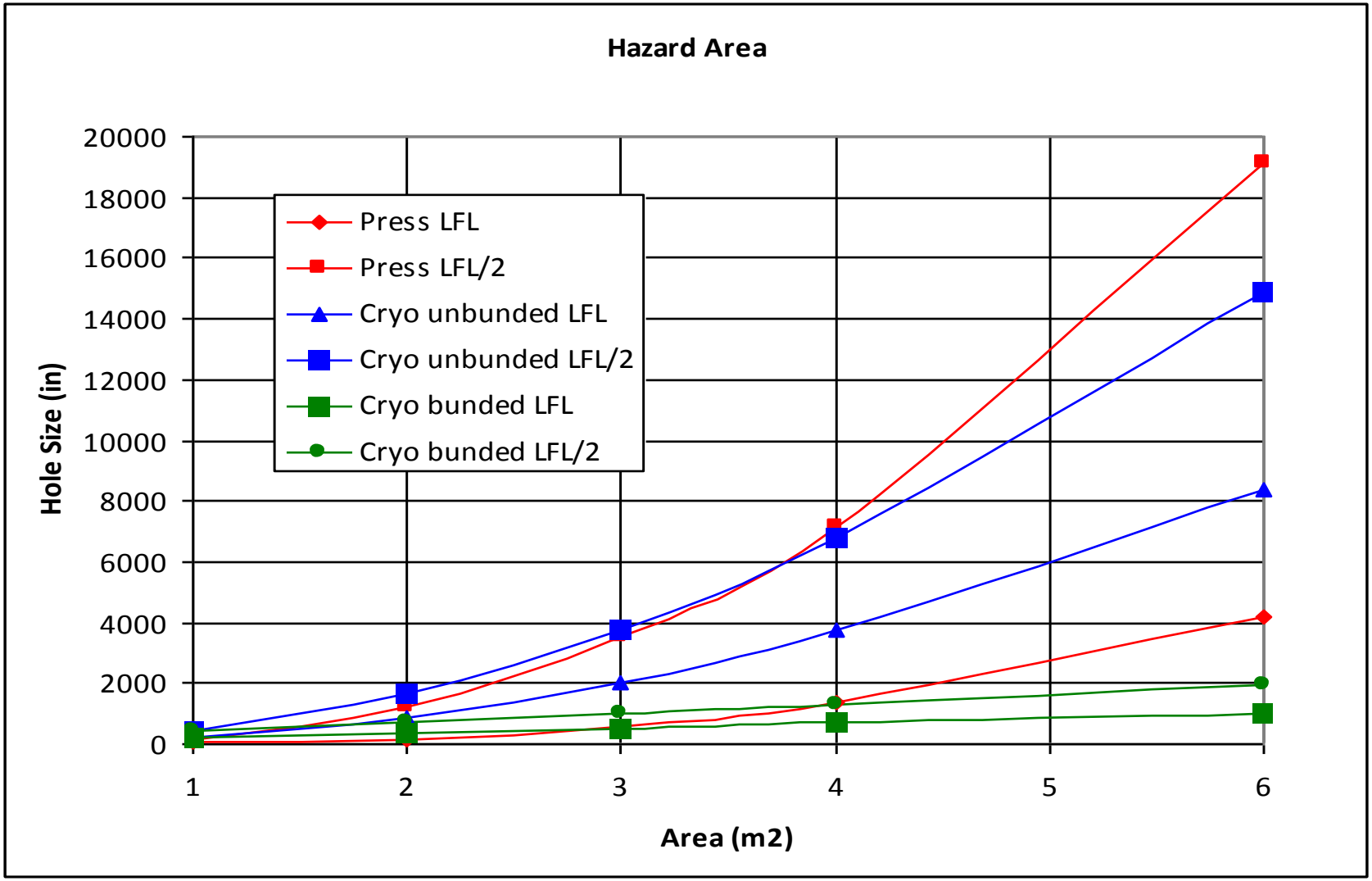
Hole size	Pressurised (kg/s)	Cryogenic (kg/s)
1”	2.8	1.7
2”	11.4	6.9
3”	25.6	15.5
4”	45.5	27.6
6”	102.3	62.2

Based on horizontal release at 1m elevation, 15°C, 1m pipe, 5m liquid head

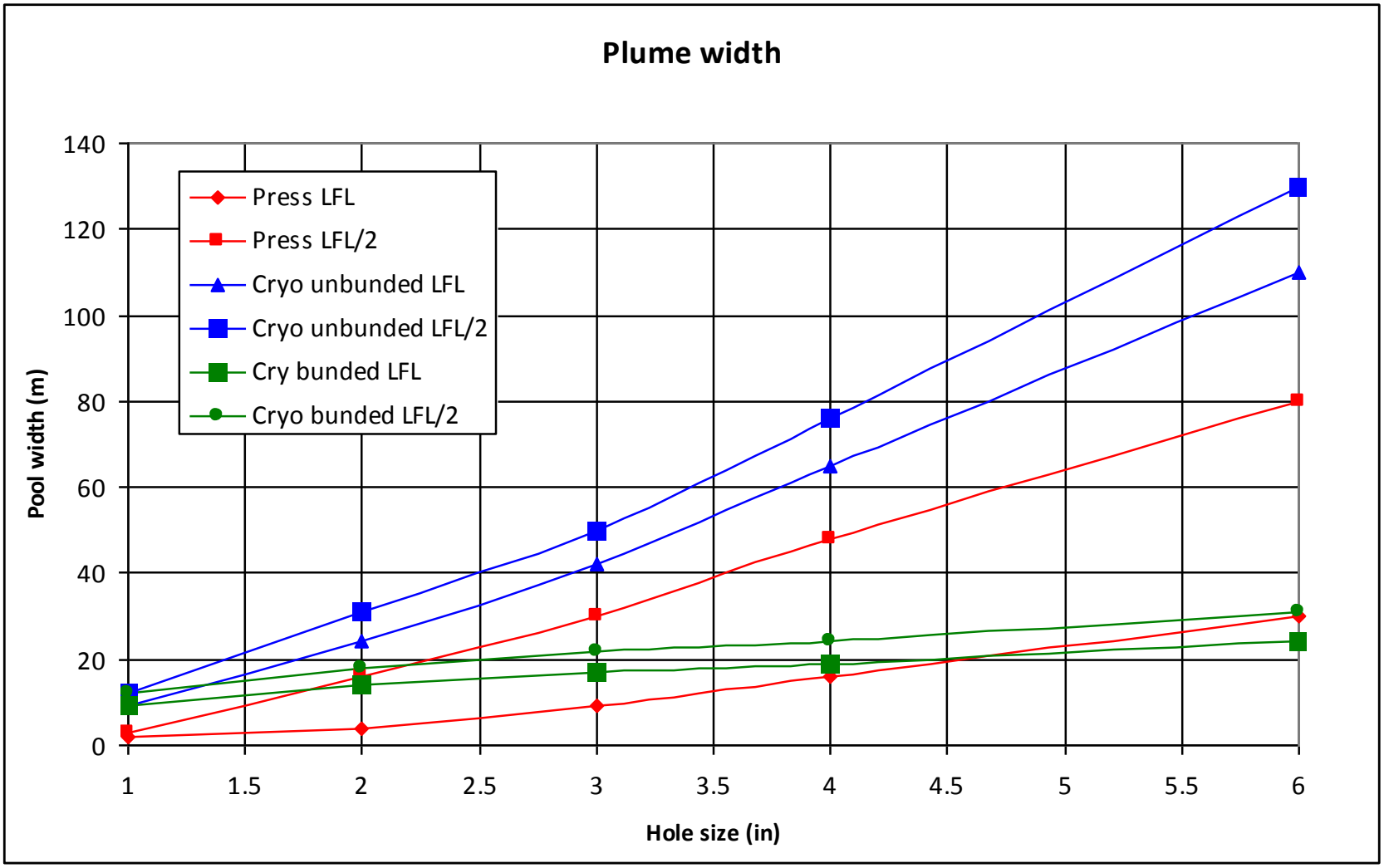
Flammability range based on hole size



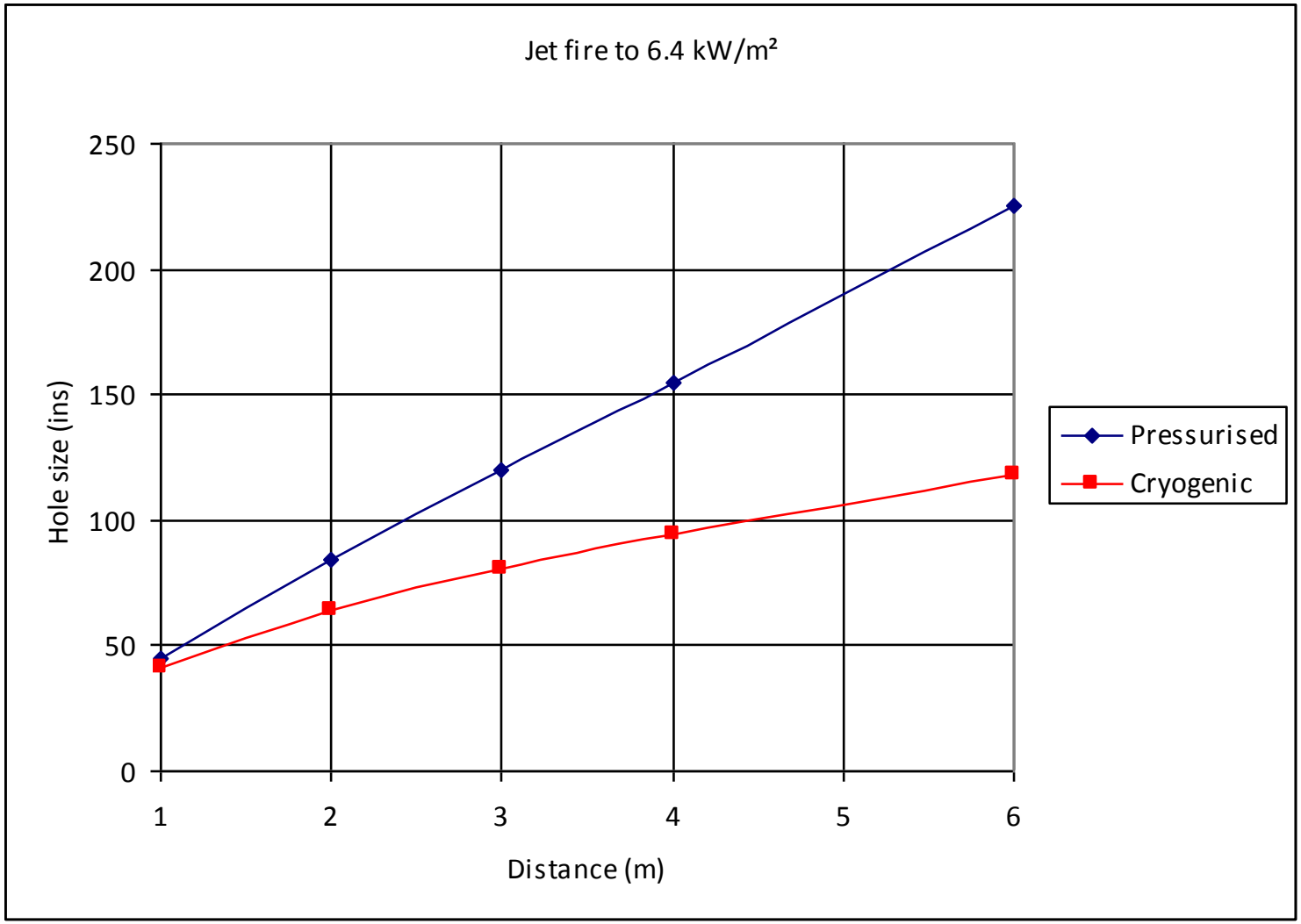
Hazard Area


Hazard Area
Hole Size (in)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
Area (m2)
Press LFL
Press LFL/2
Cryo unbunded LFL
Cryo unbunded LFL/2
Cryo bunded LFL
Cryo bunded LFL/2

Cloud width


Plume width
Pool width (m)
Hole size (in)
Press LFL
Press LFL/2
Cryo unbunded LFL
Cryo unbunded LFL/2
Cry bunded LFL
Cryo bunded LFL/2
0
20
40
60
80
100
120
140
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6

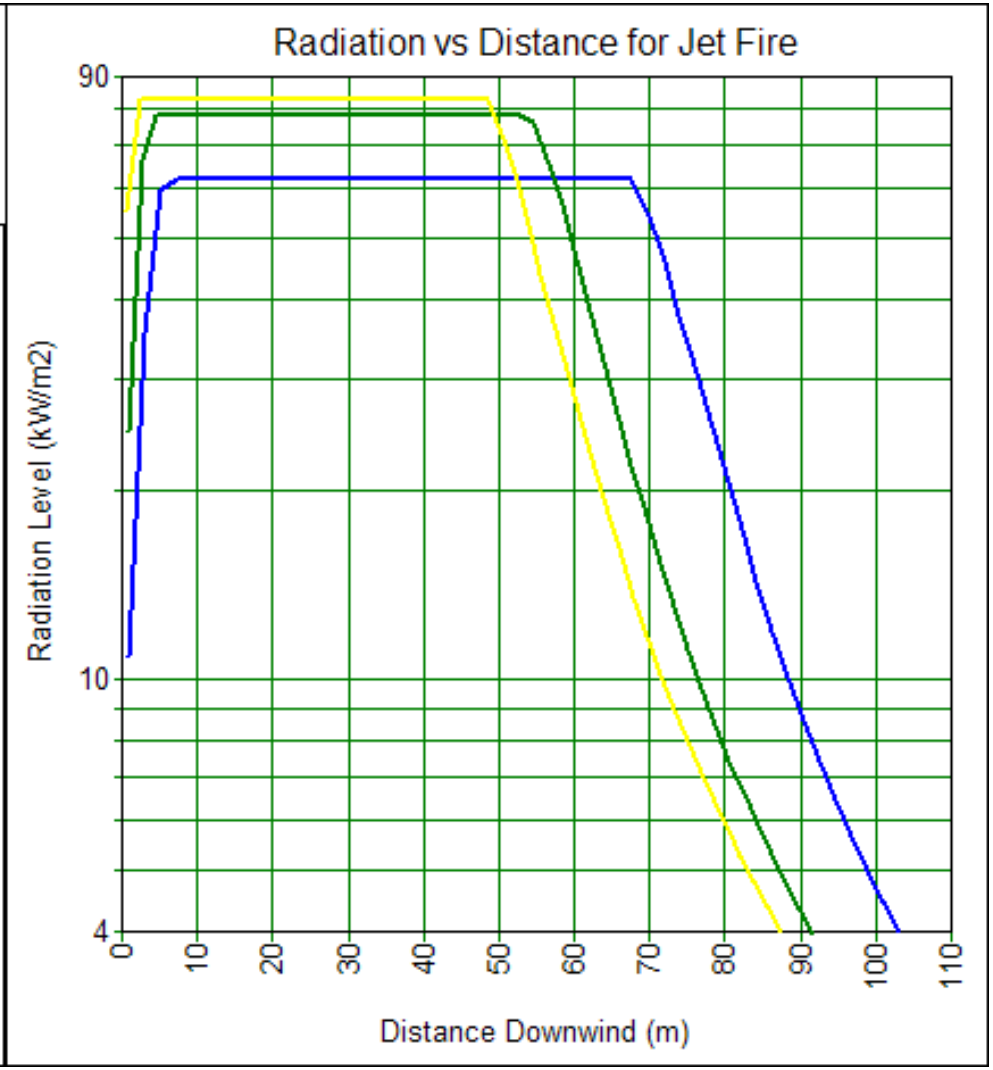
Jet fire to 6.3 kW/m²



Effect of weather conditions on jet fire

Study Folder: UKELG 2012
Audit No. 6439
Model : 2" release
Material: PROPANE
Weathers

F2
D5
D10



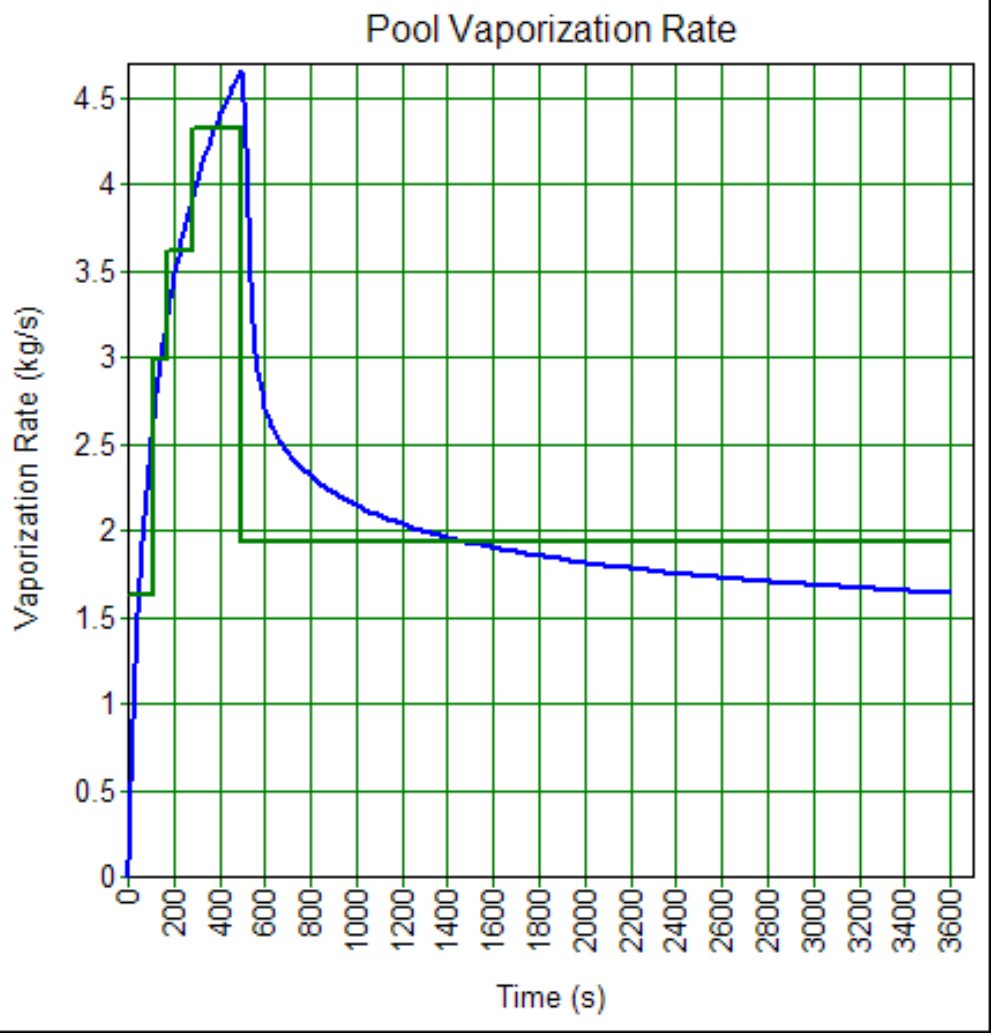
Cryogenic release

- Initial flash of material - heat transfer from ground / atmosphere
- Vaporisation rate falls as ground is cooled
  - Hazard range large for 1 - 2 minutes then falls
  - Sensible heat transfer from ground surface
- Ambient heat transfer dominates
- Size of bund is important
- Atmospheric conditions e.g. solar radiation
- Bund has negligible effect on pressurised release

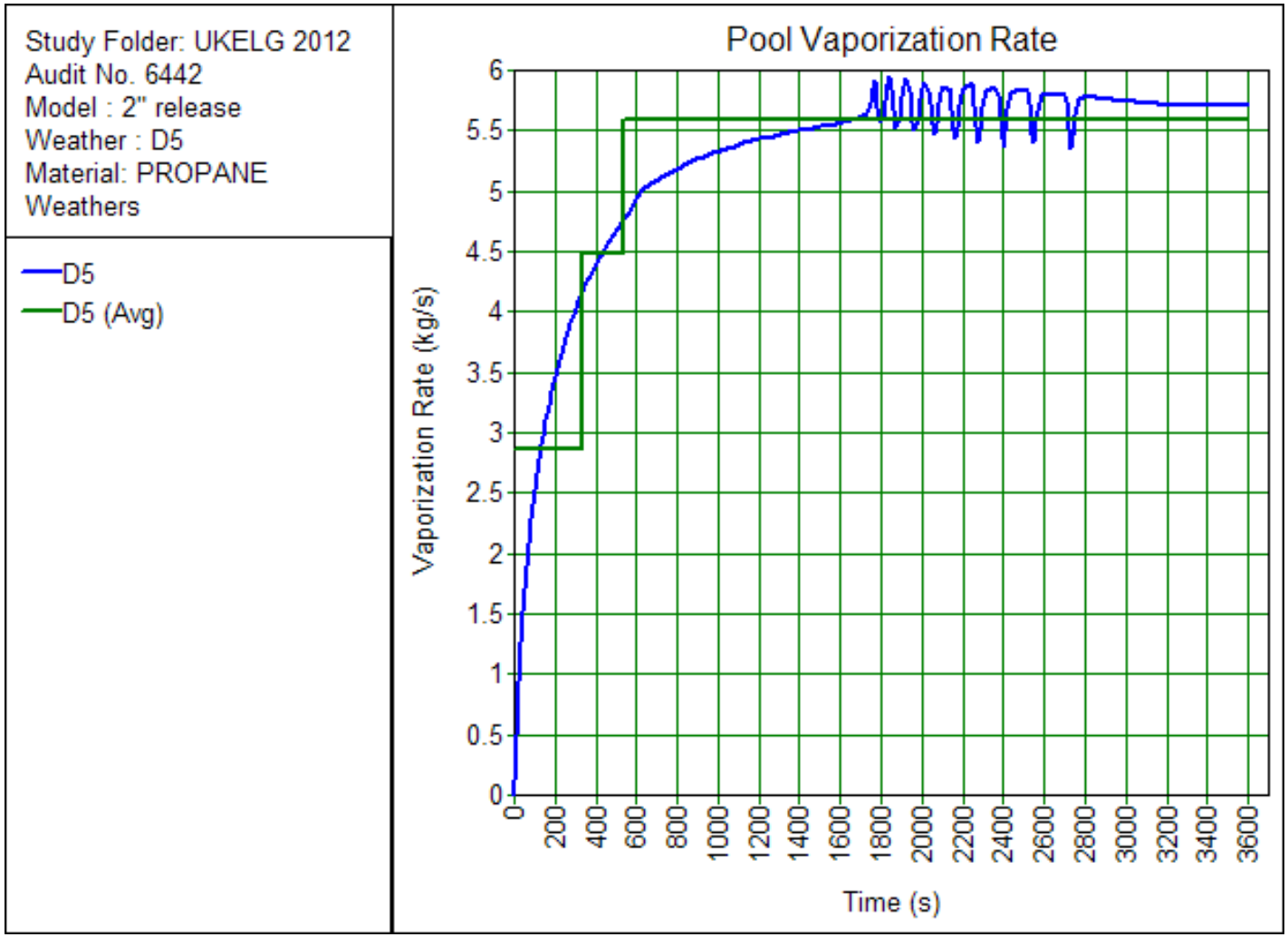
Pool vaporisation (bunded)

Study Folder: UKELG 2012
Audit No. 6442
Model : 2" release
Weather : D5
Material: PROPANE
Weathers

D5
D5 (Avg)



Pool vaporisation (unbunded)



Modelling conclusion

- Bunded cryogenic release minimises size of flammable cloud for given releases
- Bunding of pressurised releases has negligible effect on the size of flammable cloud
- Jet releases can disperse faster than cryogenic liquid in some cases

LNG versus LPG (horizontal release)

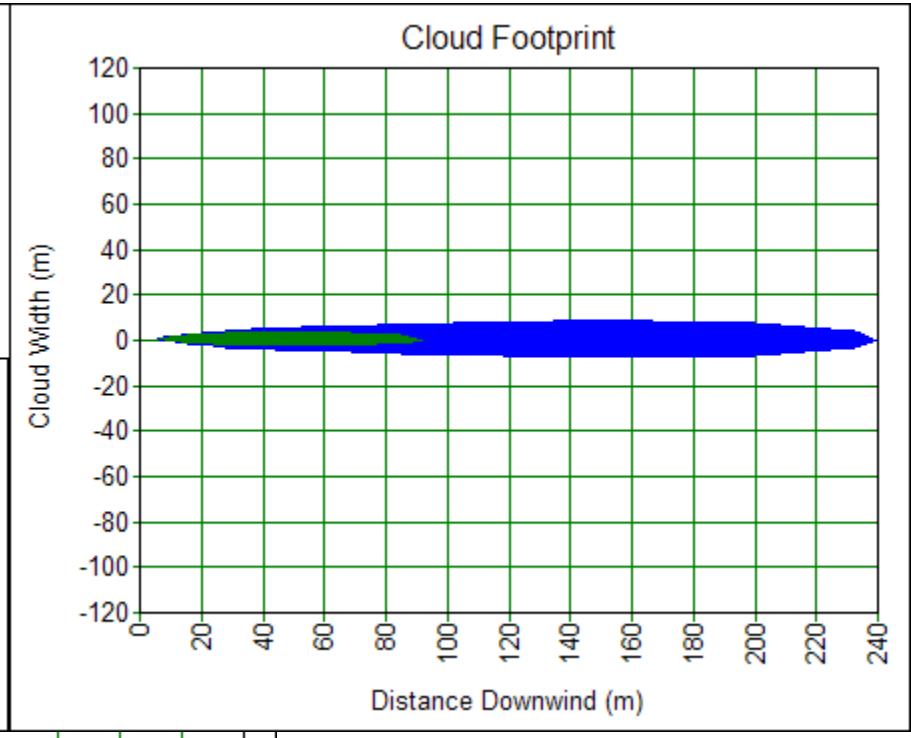
- LNG storage temp -100°C, LPG -50°C
- LNG - longer hazard ranges (up to 2x) but significantly smaller area
- Similar jet fire hazard range
- LNG has higher mass flow for given hole size (approximately 2x LPG)
- LNG vaporises much faster

Comparison of 4” release

Graphs to same scale for 4” liquid release, no bund, same conditions

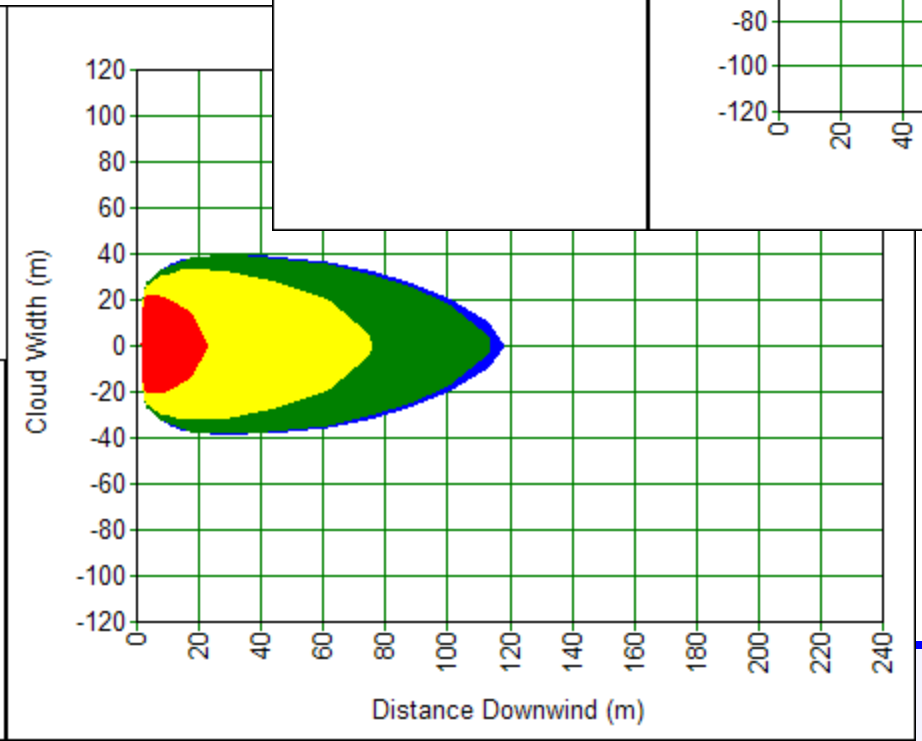
Study Folder: UKELG 2012
Audit No. 7484
Model : Cryo LNG 4" release
Weather : D5
Material: METHANE
Averaging Time:
Flammable(18.75s)
Height 0 m
Concentration
Time: 19.93 s

2952 m2 @ 2.2E4 ppm
424 m2 @ 4.4E4 ppm



Study Folder: UKELG 2012
Audit No. 7484
Model : 4" release
Weather : D5
Material: PROPANE
Averaging Time:
Flammable(18.75s)
Height 0 m
Concentration
Time: 982.8 s

7087 m2 @ 1E4 ppm
6768 m2 @ 1.05E4 ppm
3725 m2 @ 2E4 ppm
664 m2 @ 9.5E4 ppm



LNG at -100°C
LPG at -50°C

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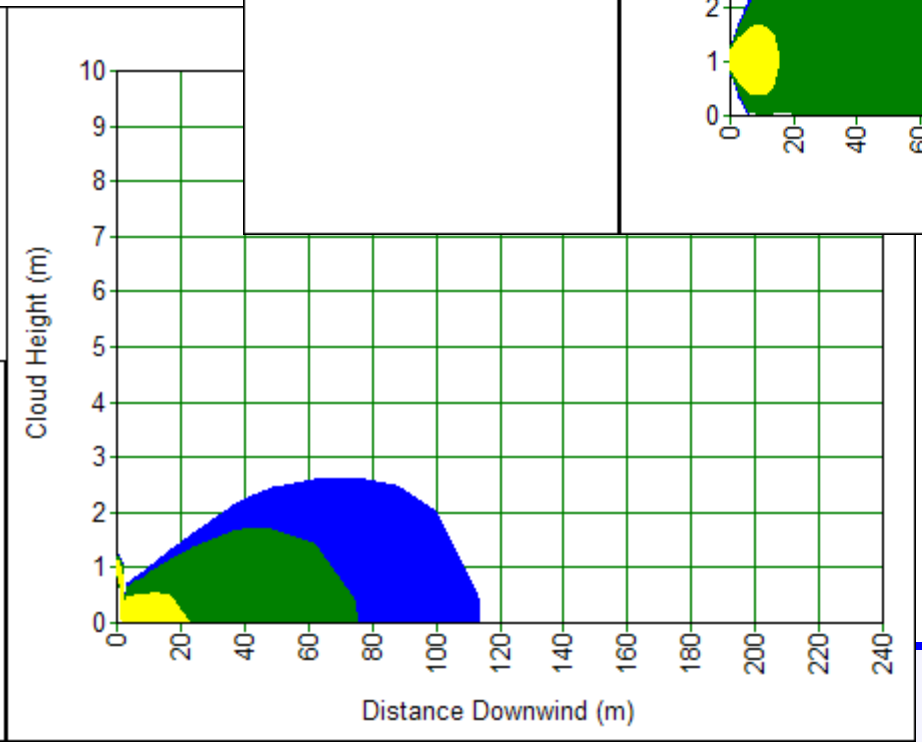
Side view

Study Folder: UKELG 2012
Audit No. 7484
Model : Cryo LNG 4" release
Weather : D5
Material: METHANE
Averaging Time:
Flammable(18.75s)
C/L Offset 0 m
Concentration
Time: 19.93 s

2.2E4 ppm
4.4E4 ppm
1.65E5 ppm

Study Folder: UKELG 2012
Audit No. 7484
Model : 4" release
Weather : D5
Material: PROPANE
Averaging Time:
Flammable(18.75s)
C/L Offset 0 m
Concentration
Time: 981.8 s

1.05E4 ppm
2E4 ppm
9.5E4 ppm



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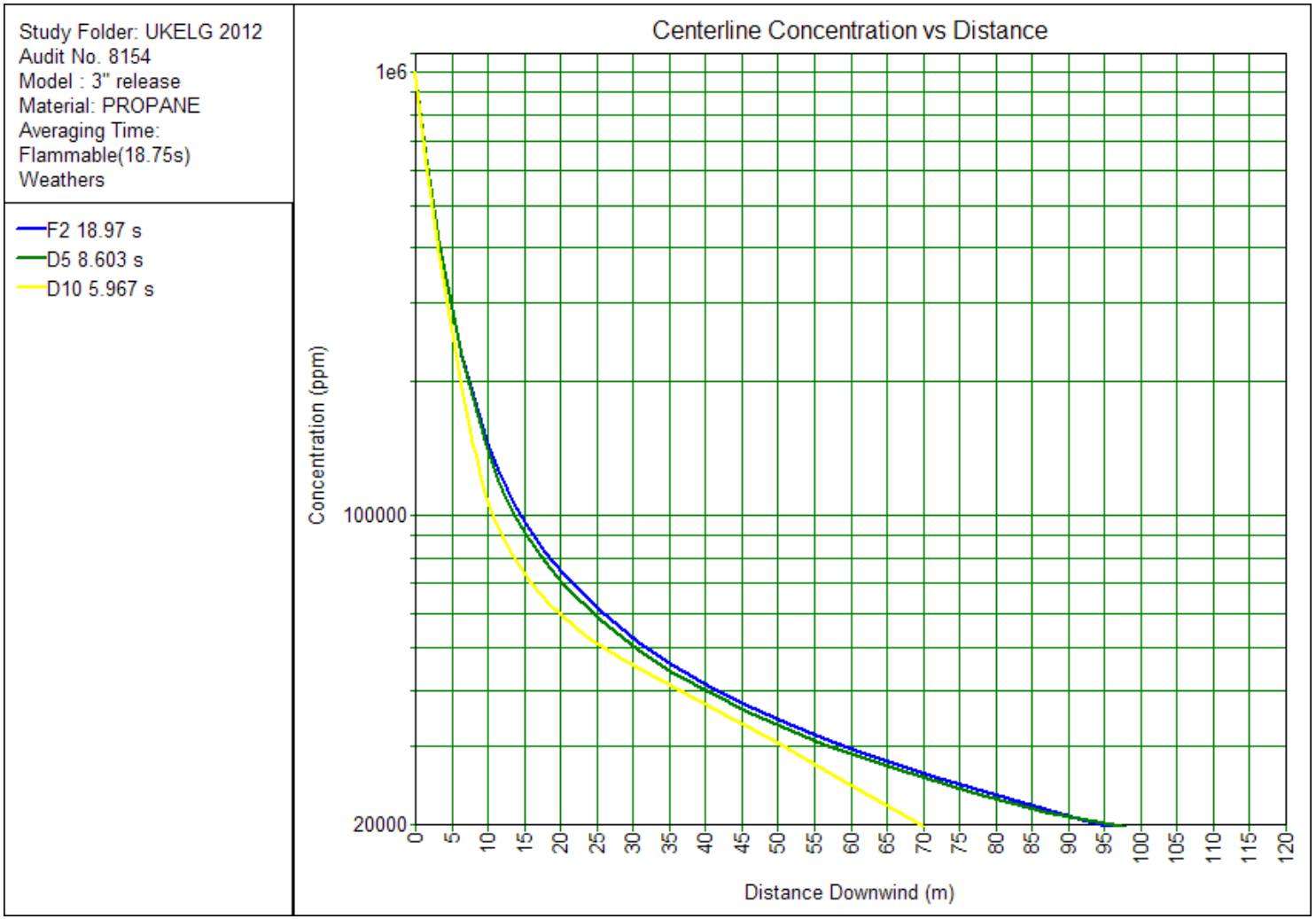
Effect of weather

Brief discussion

Weather conditions

- Normally model:
  - D5: Typical UK conditions (~40%)
  - F2: Worst case for dispersion
  - D10 / D15: High wind speed
- Based on local conditions / weather data
- Appropriate temperatures

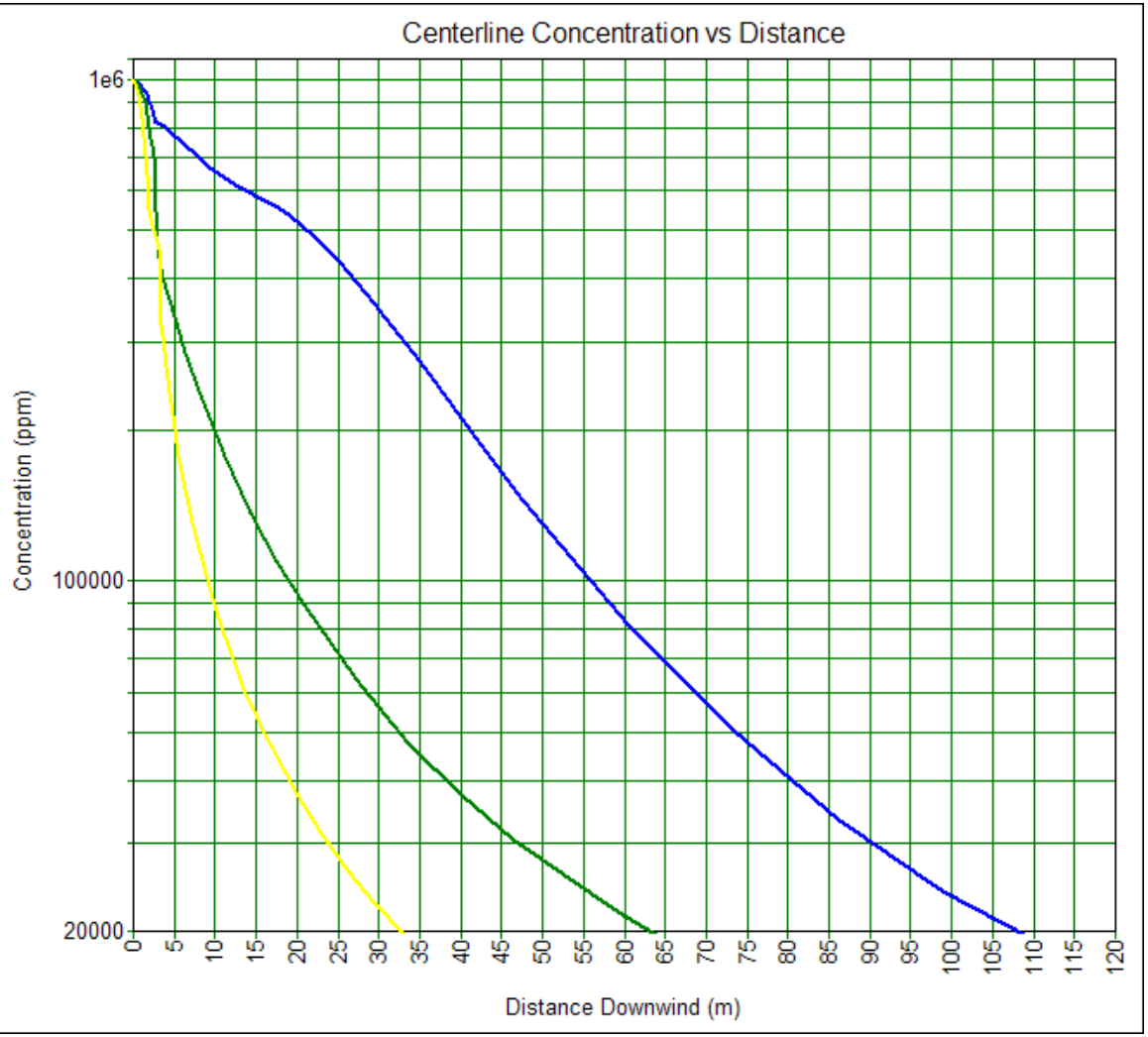
Pressurised



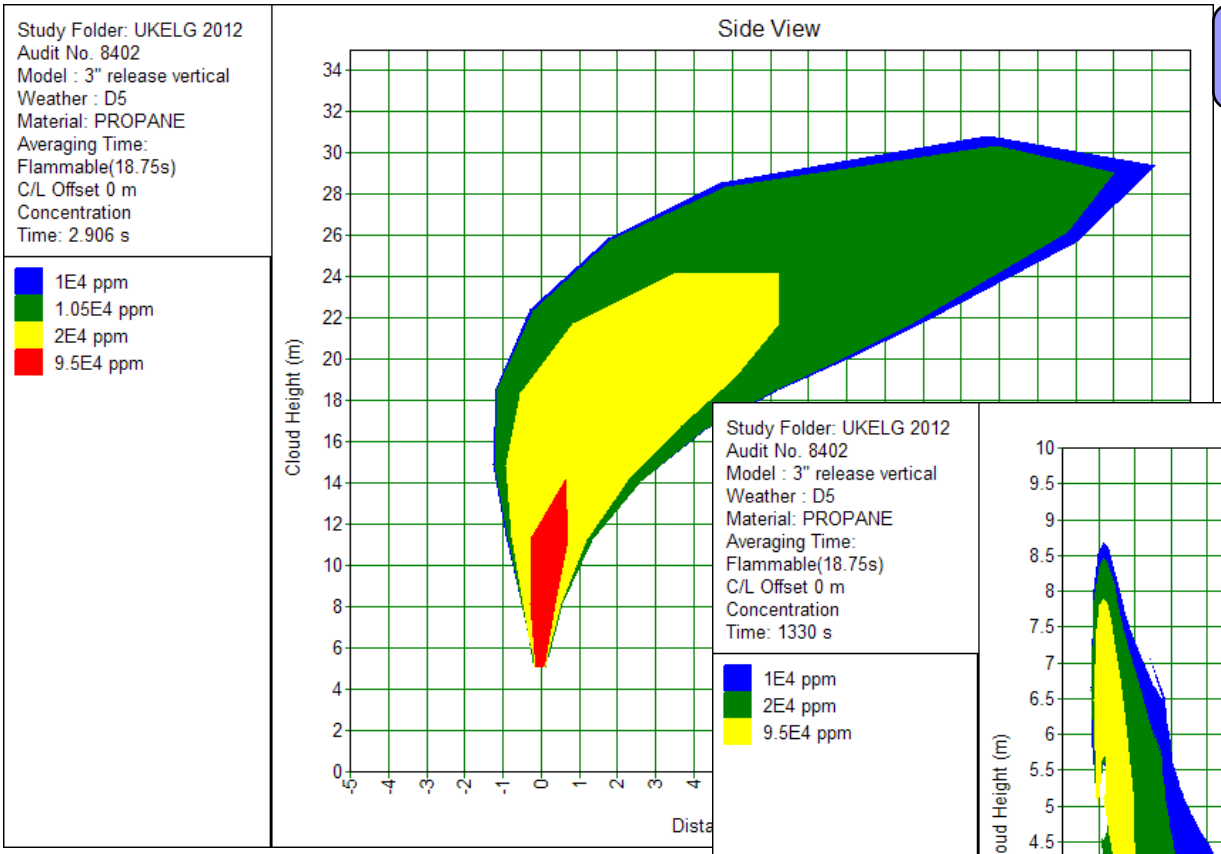
Cryogenic

Study Folder: UKELG 2012
Audit No. 7792
Model : 3" release
Material: PROPANE
Averaging Time:
Flammable(18.75s)
Weathers

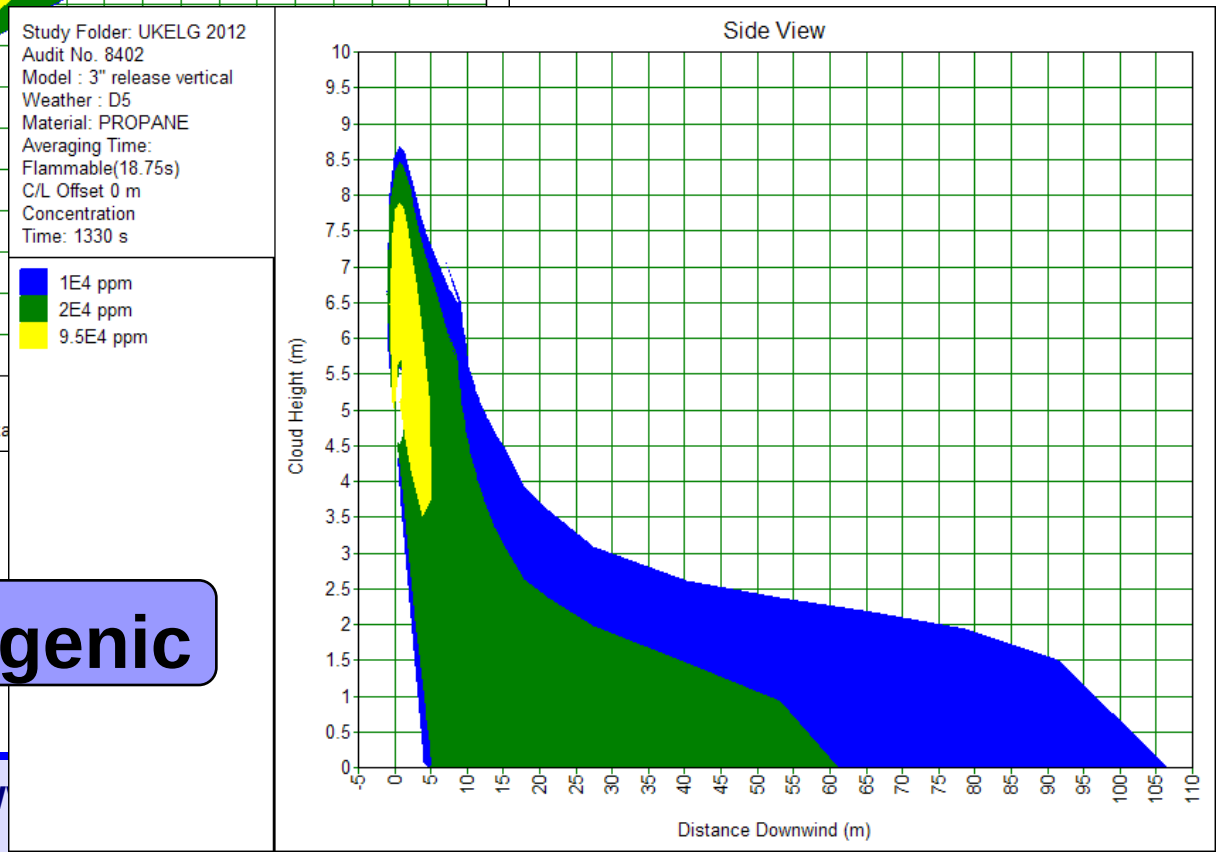
F2 799.6 s
D5 443.3 s
D10 389 s



Vertical propane releases

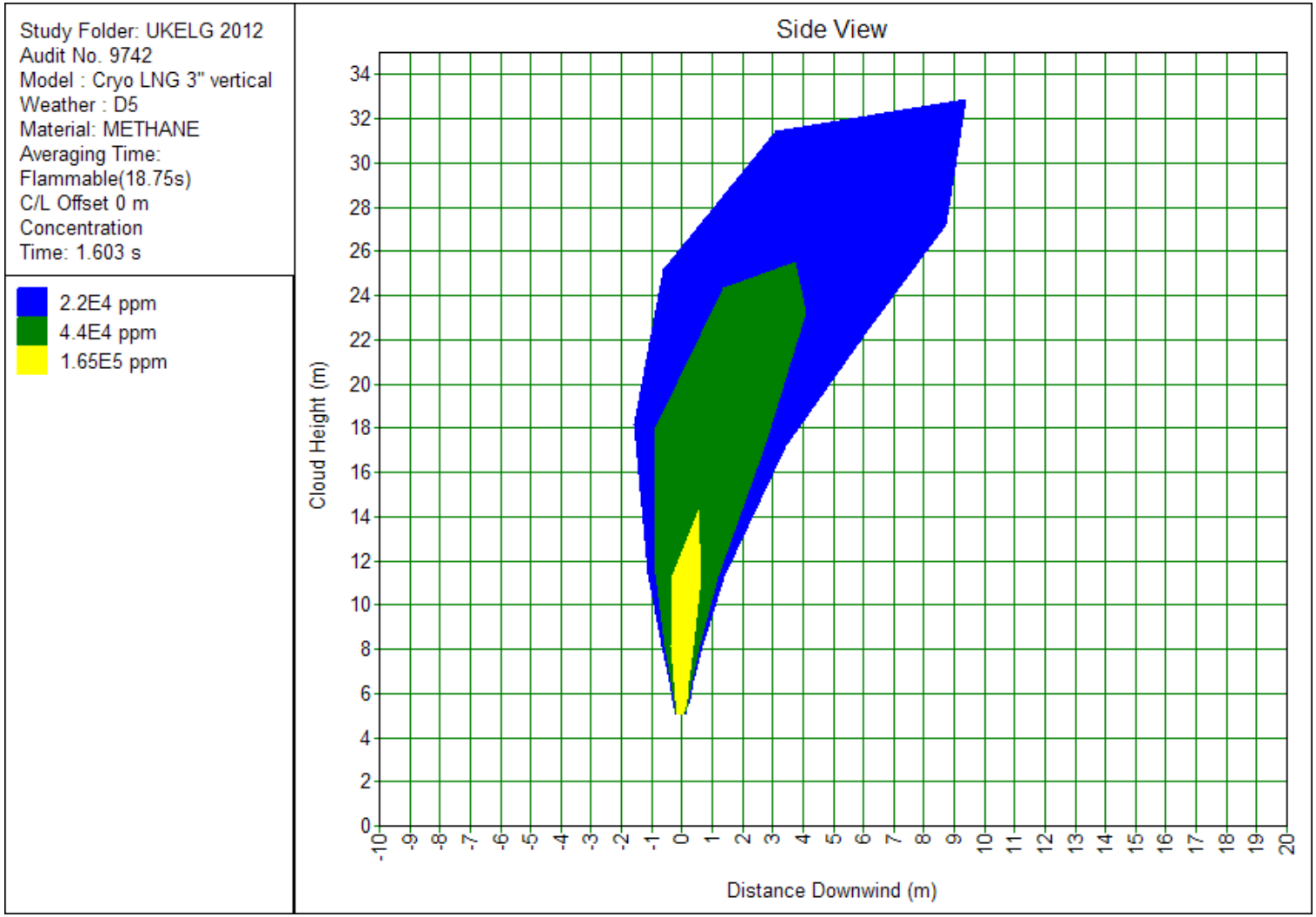


Pressurised



Cryogenic

Vertical cryogenic LNG .....



Effects

- D5: Base case
- F2: Generally gives largest plume
  - Stable atmosphere, low temperature, low wind speed
- D10 / D15: High wind speeds give thin and relatively short plumes
  - Wind shear & turbulence break up plume

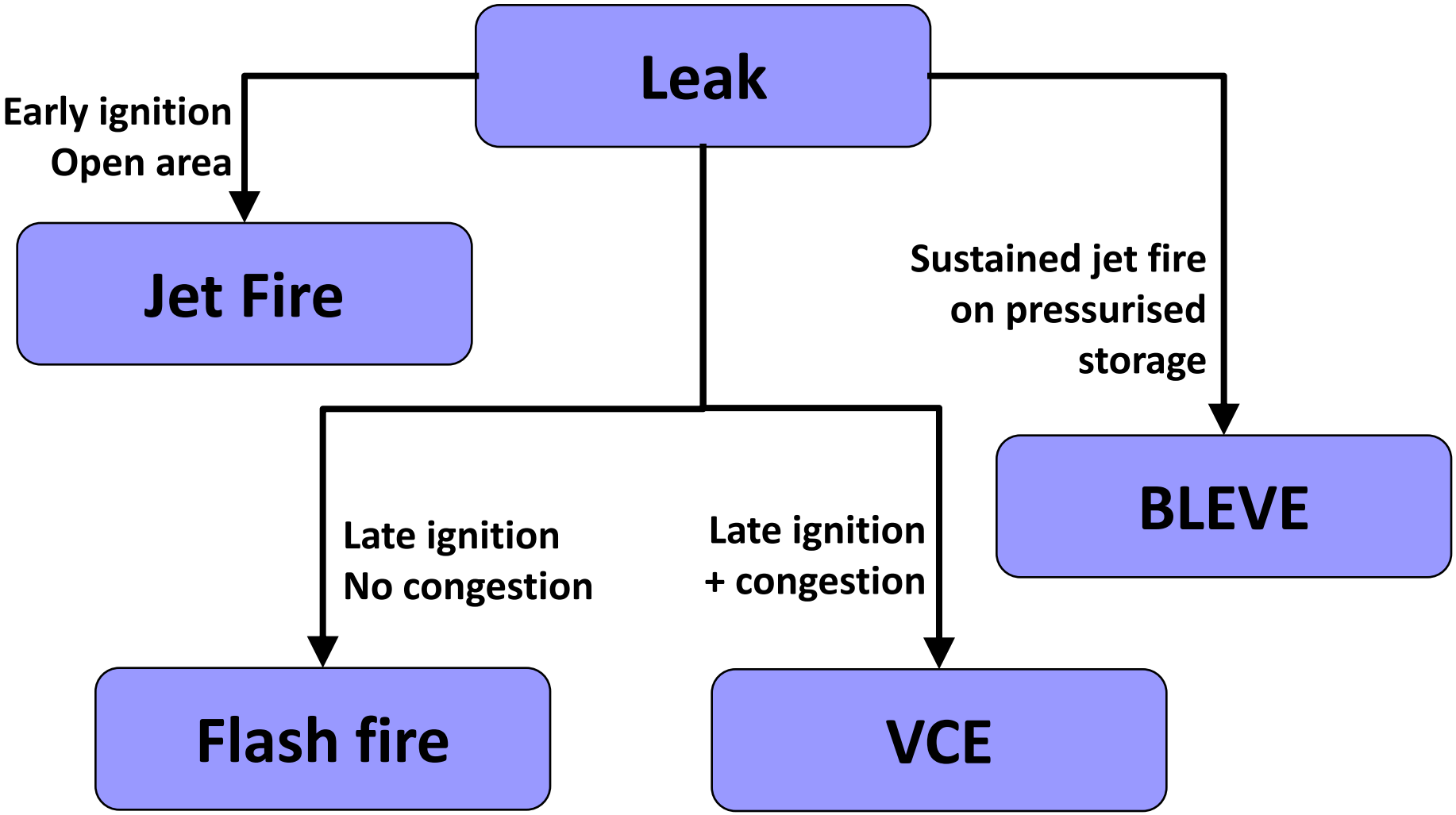
Hazard Assessment

After modelling, assess the impact, extent & severity

Assessment

- Based on plant configuration
- Pipe sizes
- Credible loss of containment events
- Inventory
- Location issues
- Weather / wind direction

Possible outcomes



Effects

Event	Effects
Jet fire	Thermal radiation; long duration depending on inventory. High thermal flux in jet flame
Flash fire	Thermal radiation; short duration
VCE	Blast overpressure, flame; very short duration. Domino effects from blast
BLEVE	Thermal radiation; short duration (depends on inventory). Vessel fragments & domino effects

Ignition Probability

Vapour Release (te)	Ignition Probability
1	0.6
10	5
100	15
1000	40

Approximate values for ignition of vapour clouds

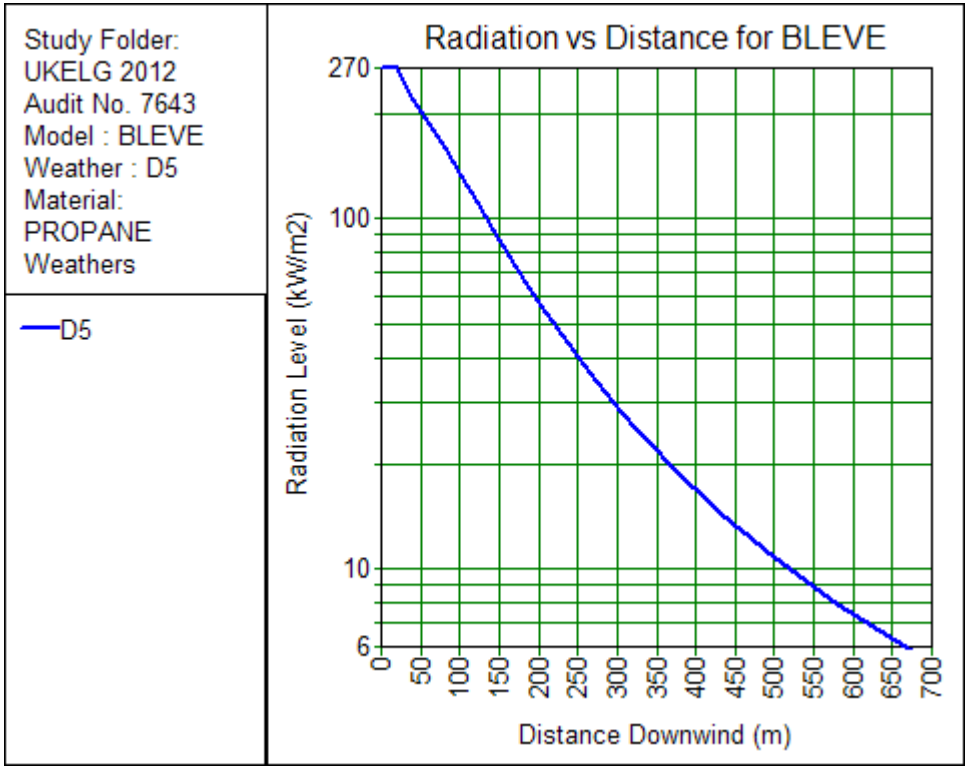
Ignition / Explosion Risk

- Dependent on:
  - Mass released
  - Congestion / Confinement
  - Ignition source presence
- Large release = high probability of reaching an ignition source
- Ignition sources => Off plot / uncontrolled
- Hazardous Area Classification?

Hazard

- Vapour cloud enters building or congested structure
- Ventilation rate?
- VCE volume?
- Ignition sources?

BLEVE



- Extended thermal radiation on pressurised storage
- Rupture of pressure vessel (petal failure)
- 100 te BLEVE ~20 sec duration
- Minimal overpressure large thermal radiation level

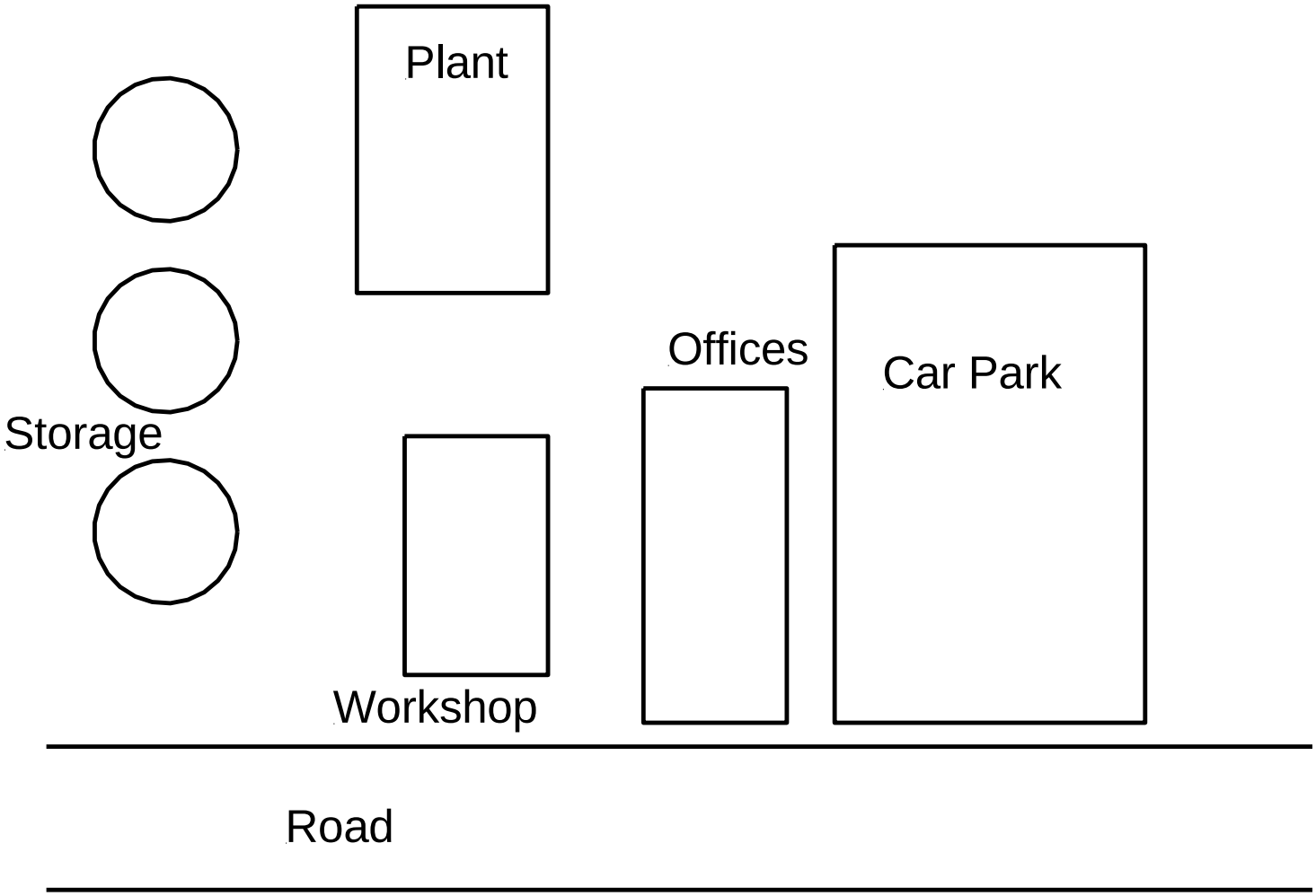
Mexico City BLEVE

Mexico City #2

Site Hazard Assessment

- Release sources
- Hazard ranges
- Impingement of jet or pool fire
- Size of cloud
- Congested / confined areas
- Potential for ignition
- Domino effects
- Feed results back into HAZOP / PRA

Typical site



Congestion?

Comparison

Pressurised

- Higher release rate for given hole size
- Faster flash of liquid released
- Jet fire & BLEVE
- Tends to disperse more easily (temperature)
- Release orientation important
- Invisible release

Cryogenic atmospheric

- Atmospheric pressure, leak rate based on liquid head
- Flash rate depends on ambient conditions
- Pool fire, no BLEVE
- Slower to disperse
- Cold, dense cloud – slumps to ground in many cases
- Visible release (condensation)

Conclusions

- Not always initially clear what the worst case will be
- Density relative to air
- Take into account geography of plant
- Look at realistic release cases
- Cryogenic generally lower hazard than pressurised
- Bunds have significant effect
- Need to carry out careful & detailed analysis
- LPG & LNG dispersion very different