

# Gasoline Pipelines – Proposed UKOPA Methodology for Quantified Risk Assessment to obtain Land Use Planning Zones

## Objectives

- To produce a realistic approach based on actual releases
- Simple, easy-to-apply methodology
- Sufficiently comprehensive to allow risk reduction measures to be incorporated
- Generic, but able to be applied more specifically to site specific cases
- To gain operator buy-in to the approach

# History / Background

- 5 key reports produced in 1990s, 4 of particular interest
- W S Atkins Report 1998 “Assessing risks from Gasoline Pipelines in the UK based on historical experience”
- A D Little 1996 report – published as HSE Contract Research report 206/1999
- HSE Gasoline Pipelines Risk Assessment Methodology 1999 – PIPERS methodology
- HSE produced RR036 More Pipeline Accidents analysed using MISHAP and PIPERS in 2002

## History / Background

- Reports analysed and discussed Gasline operators meeting 25 November 2003
- Concerns with HSE's approach – most of the risk due to pinhole release causing 100 metres diameter pool taking 24 hours to fill – no one escapes in area where pool burns in 15 minutes – also anomalies with PIPIN failure rates
- Concerns expressed to HSE 10 December 2003
- Further discussions with Steve Porter April / May 2004
- July 2004 Decision not to proceed with PSR amendments

# Main Elements of Proposed Methodology

- 1 Inner Zone based on “equilibrium” pool fire
- 2 Middle & outer zones risk-based
- 3 Three hazards scenarios – spray fire, immediate ignition pool fire, delayed ignition pool fire
- 4 Failure rates based on UKOPA and CONCAWE data
- 5 Sprays formed for 16% of releases
- 6 Source of Ignition 0.1 for spray fires, 0.025 for immediate pool fires and 0.025 for delayed pool fires
- 7 Shut-off time 5 minutes for delayed pool fire
- 8 100% gasoline in pipeline
- 9 Ground soak-in 50% of the time, reduces pool diameter to 70% of no-soak-in case
- 10 100% effect impact on population within fire and out to 14.7 kw/m<sup>2</sup>

## Inner Zone – how do we define Inner Zone for Gasoline Pipelines?

- **Other substances – Fireball Radius (ethylene, spiked crude)**
- **2001-2 – Natural gas pipelines – changed to Building Proximity Distance as defined by IGE/TD/1**
- **For gasoline, worst case with low chance of escape (inside buildings) would be immediate ignition pool fire**
- **BUT size of pool fire is dictated by release rate from pipeline –  
- dependent on pumping rate, NOT pipeline pressure**
- **Therefore propose that Pipeline Operator declares maximum pumping rate as part of notified information, so allowing Inner zone to be calculated from equilibrium pool fire radius**
- **Assumes no ground soak-in**

## Calculation of equilibrium pool fire

The equation for calculating the equilibrium diameter of a gasoline pool is as follows:-

$$D_{\max} = 2 \cdot \sqrt{\frac{m_r}{\pi \cdot m_f}}$$

where D = maximum diameter of pool fire, metres

$m_r$  = release rate of gasoline into pool kg/sec

$m_f$  = burning rate of gasoline kg/sec.m<sup>2</sup> = 0.067 for large pool fires

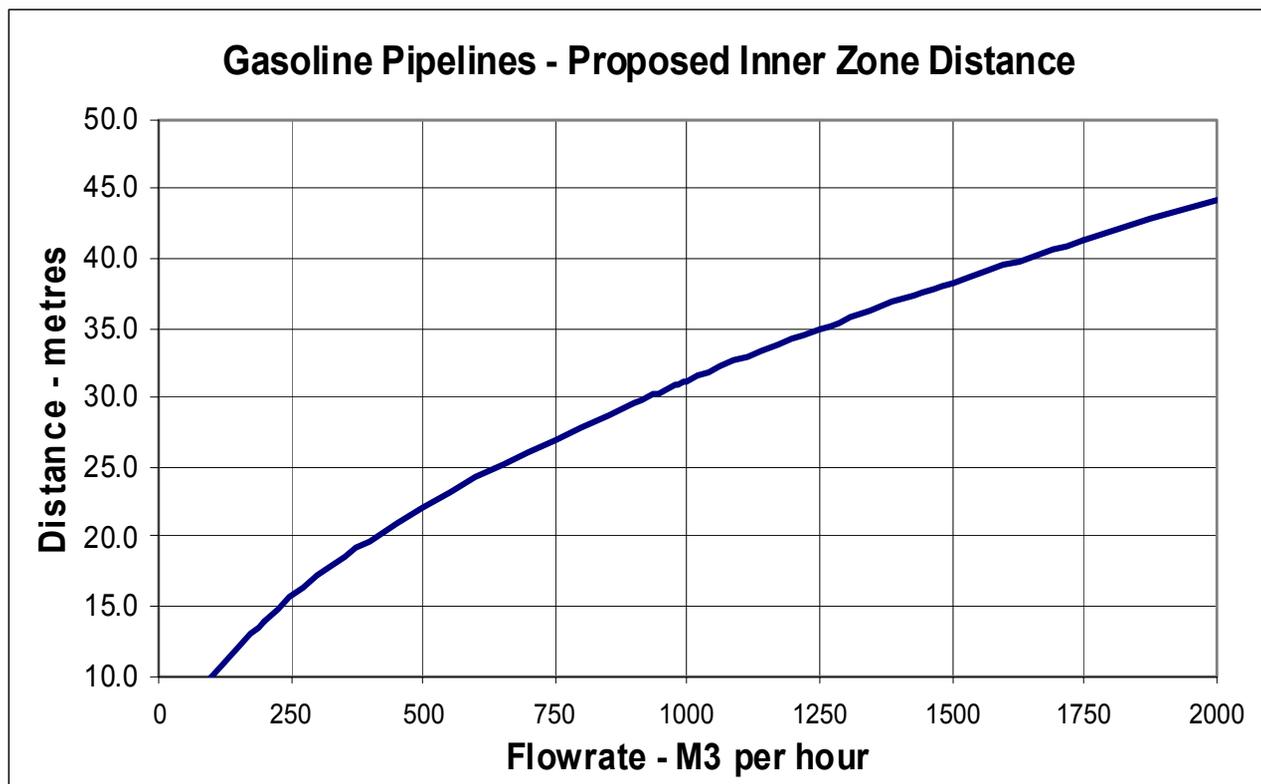
This may be simplified to:-

$$Radius = \sqrt{0.976573 \times flowrate(m^3 \text{ per hour})}$$

This then defines the inner zone distance for pipeline flowrates as follows:-

# Resulting pool fire radii distances as shown:-

Flowrate m <sup>3</sup> /hour	Inner Zone
50	7
100	10
200	14
300	17
400	20
500	22
600	24
700	26
800	28
900	30
1000	31
1200	34
1500	38
1750	41
2000	44



**Proposed that these should be applied as Inner Zone Distances**

## Application of QRA to obtain Middle and Outer Zones

### Key notification data for current MAHPs:

6 items:-

- 1 Pipeline diameter
- 2 Pipeline wall thickness
- 3 Maximum Allowable Operating Pressure
- 4 Population Classification – Rural or Suburban (R & S)
- 5 Depth of Cover
- 6 Material of Construction (steel grade)

### **ADDITIONAL INFORMATION FOR GASOLINE PIPELINES**

- Maximum throughput

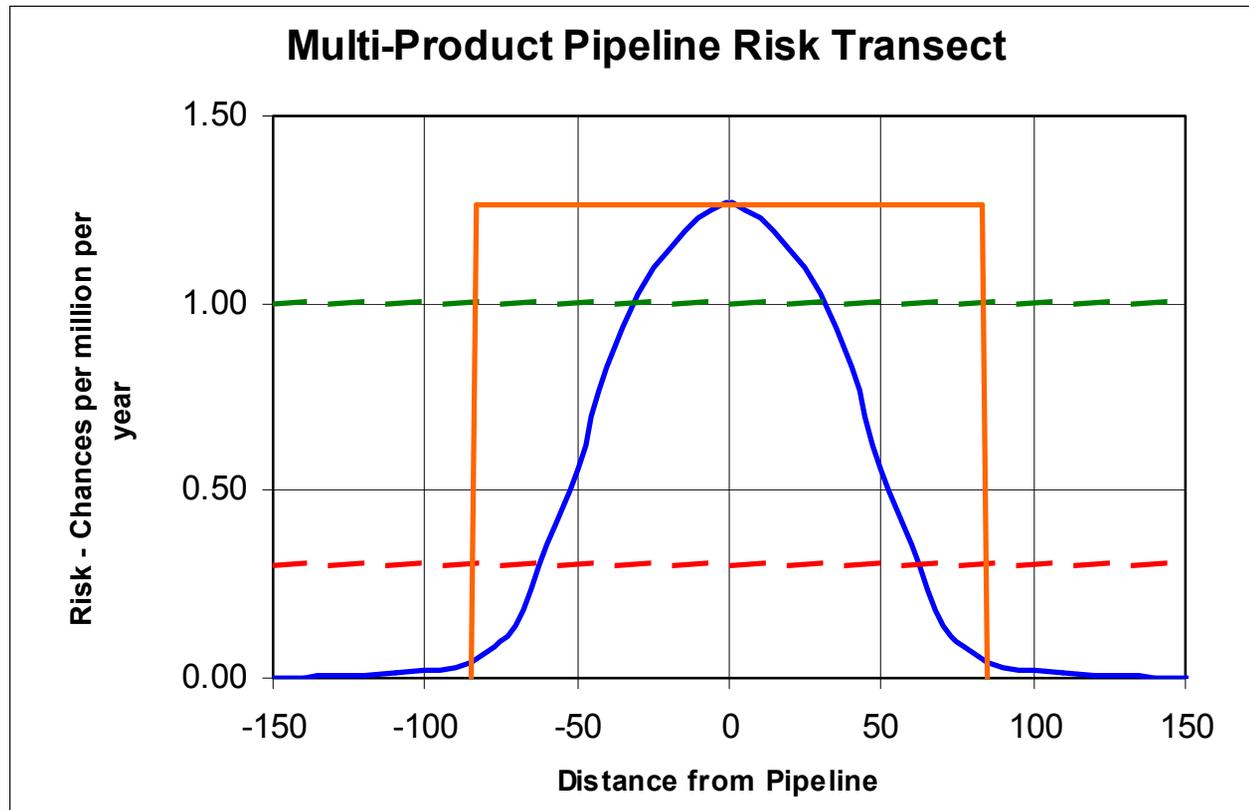
## KEY PARAMETERS AFFECTING SAFETY RISK ASSESSMENT

- Pipeline failure mechanisms and size
- Failure Rates for generic failure mechanisms
- Hazard scenarios - spray fire, immediate or delayed pool fire, no ignition
- Release rate
- Product flowing at the time – gasoline or high flash (kero-type) product?
- Response time of operators shutting off flow
- Amount released during response time, depressurisation and drain down
- Hole size to cause spray
- Ignition probability
- Probability of escape
- Fire and thermal radiation effects

# QRA applied to Gasoline Pipelines

Why make it complicated?

1. Multiple scenarios give graduated risk with distance from pipeline
  - simple models give more pessimistic zone distances



# Key elements of Gasoline QRA Methodology

- 1. Multiple scenarios give graduated risk with distance from pipeline**
  - simple models give more pessimistic zone distances**
- 2 Apply realistic scenarios based on actual experience**
- 3 Allow for risk reduction effects / engineering improvements to reduce risk levels**
- 4 Allow case specific planning applications to be assessed using factors relevant to specific locations**

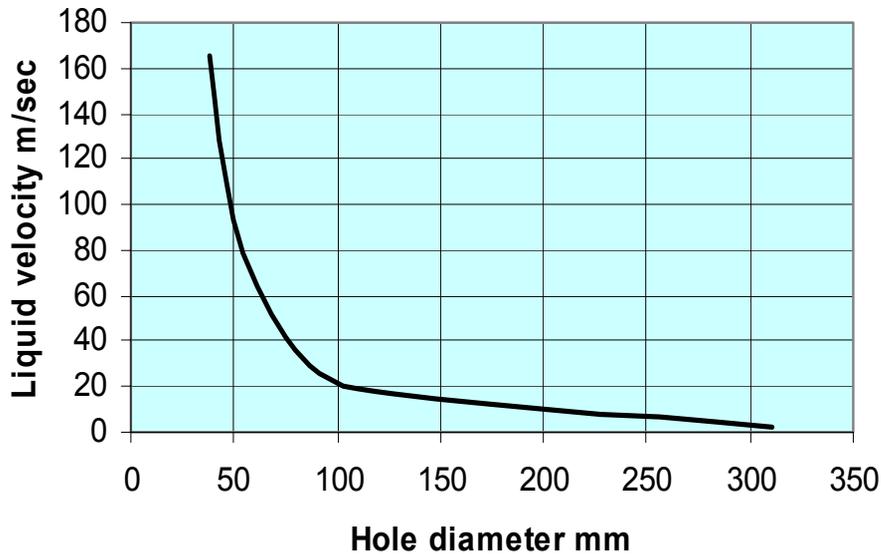
## Three hazard scenarios proposed:-

- **Spray fire**
- **Immediate ignition pool fire**
- **Delayed ignition pool fire**

# CAUSES OF SPRAYS AND EFFECTS

- Atkins analysis of nearly 300 incidents worldwide showed ~ 16% caused sprays, only 3.5 % included a definite reference to sprays
- Velocity through hole indicates medium-sized holes cause serious risks from sprays
- Atkins suggest 2 x pressure in bar as max. range
- Modelled as 4 ellipses with length 100%, 75%,50% and 25% max. range and width 80% x length

Release Velocity Vs Hole Size



- **Elliptical profile – lower overall risk contribution**
- **For 100 bar pipeline pressure**

Spray fire probability	Spray fire effect distance	Spray fire effect width
25%	200 metres	160 metres
25%	150 metres	120 metres
25%	100 metres	80 metres
25%	75 metres	60 metres

# 1 Spray fire analysis in Proposed Methodology

- Sprays assumed to occur for 16% of releases
- Maximum effect distance = 2 x MAOP of pipeline  
(anywhere along length even though pressure is normally lower)
- Four equal-probability scenarios are evaluated, 100% of effect distance, 75%, 50% and 25%
- Elliptical shape with minor axis (width) = 80% of major axis (length)
- Probability of ignition = 0.1 (10%)
- Takes flash fire into account

## 2 Immediate Ignition Pool Fire

- Diameter governed by release rate:

$$D_{\max} = 2 \cdot \sqrt{\frac{m_r}{\pi \cdot m_f}}$$

where D = maximum diameter of pool fire, metres

$m_r$  = release rate of gasoline into pool kg/sec

$m_f$  = burning rate of gasoline kg/sec.m<sup>2</sup> = 0.067 for large pool fires

- Source of Ignition probability = 0.025 (2.5%) based on historical data



Flow m <sup>3</sup> /hour	Diameter metres
200	28
300	34
400	40
500	44
1000	63
1500	77

### **3 Delayed Ignition Pool Fire**

**Typical 500 m<sup>3</sup>/hour pipeline transfer:-**

**Pool fire diameter = 44 metres release rate = burning rate**

**However, full rate pumping for:-**

**1 minute gives 20 metre diameter pool 25 mm (1 inch) deep (simple flat-earth models!)**

**3 minutes .....36 metres**

**5 minutes.....46 metres**

**10 minutes .....65 metres**

**20 minutes.....92 metres**

**Reasonable to assume ignition probability increases with pool diameter**

**Therefore RISK LEVELS become dependent on**

**speed of detection and shutoff**

### 3 Delayed Ignition Pool Fire in Proposed Methodology

- Release rate for 5 minutes before
  - Operator shuts off flow
  - Ignition occurs
- Pool depth 25 mm
- Probability of ignition 0.025 (2.5%)

# Failure Rate Data

## Review of CONCAWE Data for Product Pipelines – April 2005

- Part 1 - Considered Atkins 1997 review of CONCAWE data
- Part 2 Re-calculated CONCAWE Clean Product failure rates for 1971 – 2003
- CONCAWE (Peter Davis) allowed full access to data for leaks and exposure
- Part 3 considered application to UK Product Pipelines
- Part 4 re-calculated crude oil pipeline failure rates
- 4 reports available as UKOPA documents
- Sent to HSE – 2005-6
- Need to develop data for use by HSE in PIPIN (existing failure rates in PIPIN are suspect)

# Failure Rates

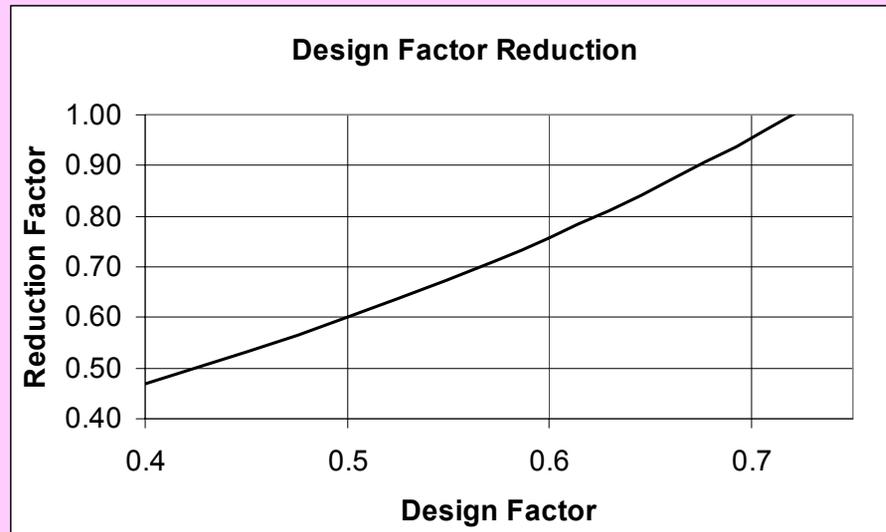
**Table 2 - Failure Rates per 1000 kilometre-years – Product Oil Pipelines in the UK**

Spillage Cause	Pinhole	Hole	Rupture	Total
Mechanical	0.025	0.022	0.012	0.059
Corrosion	0.012	0.049	0.002	0.063
Natural	0.002	0.008	0.004	0.014
Third Party	0.026	0.054	0.022	0.102
Total	0.065	0.133	0.040	0.238

**Figure 3 – Reduction in Failure Rate with Design factor**

Allow for:-

- > Thicker wall
- > MAOP - Design factor
- > Predictive modelling



**Table 2 CONCAWE Leak Size Classification**

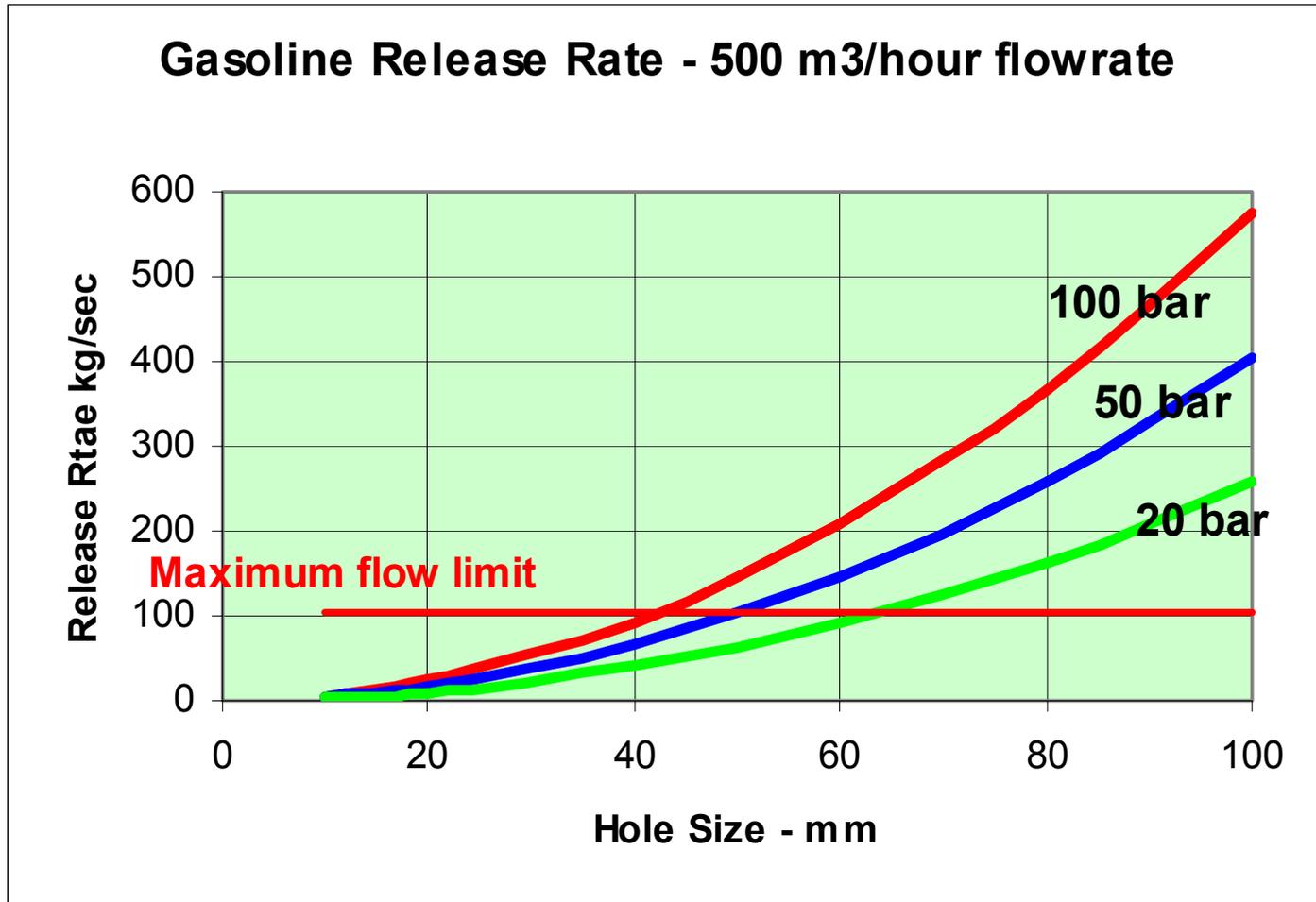
<b>Failure Mechanism</b>	<b>Rupture</b>	<b>Puncture</b>	<b>Pinhole</b>
Third party activity	> 250 m <sup>3</sup>	11 to 250 m <sup>3</sup>	10 m <sup>3</sup> or less
Corrosion	> 500 m <sup>3</sup>	11 to 500 m <sup>3</sup>	10 m <sup>3</sup> or less
Mechanical	> 200 m <sup>3</sup>	11 to 200 m <sup>3</sup>	10 m <sup>3</sup> or less
Natural	> 200 m <sup>3</sup>	11 to 200 m <sup>3</sup>	10 m <sup>3</sup> or less

**Note hole sizes are based on amounts leaked out – therefore Pinhole should not be interpreted as 25 mm hole size! –it would Release 150 m<sup>3</sup>/hour – 4 minutes to leak out 10 m<sup>3</sup>**

## 4 Failure Rate Data for Gasoline Pipeline

- 3<sup>rd</sup> party failure rate from UKOPA data Predictive models
- Mechanical and Corrosion failure rates from updated CONCAWE data for clean product pipelines in Europe (pending better data from UKOPA database)
- Ground movement failure rate from UKOPA as currently used by HSE (subject to further review by HSE?)

## 5 Liquid Release Rates from holes



Therefore maximum flowrate is discharged through 40+ mm hole

Therefore MAOP is less important than MAXIMUM FLOWRATE

**Therefore suggest hole sizes and release scenarios**

<b>Small Hole</b>	<b>10 mm hole discharge rate</b>
<b>Puncture</b>	<b>Discharges full flowrate</b>
<b>Rupture</b>	<b>Discharges 103% flowrate due to pump rate increase with lower pipeline back-pressure before tripping out</b>

**Proportion of time gasoline important because:-**

- Kerosene / diesel / fuel oil have higher flash points (40°C +) compared to below 0C for gasoline**
- Vapour pressures lower – therefore small flammable vapour probability following a release from a pipeline**
- Evidence indicates strong sources of ignition required (e.g. bonfires) required to ignite cold pools of kero/diesel etc.**
- QRA could allow for kero spray fire, but not usually a pool fire**
- Operators suggest that 100% gasoline should be assessed for LUP zones**

## **W S Atkins – Ground Soak-in**

- **Very impermeable clay soils – relatively uncommon in UK**
- **Average soil allows soak-in so that pool diameter is ~ 70% that on impermeable clay soil**
- **Very permeable soil results in small (~ 6 m diameter) pools for large release rates**
- **Waterlogged saturated or frozen likely to be similar to impermeable clays**

## 6 Pool Fire Methodology for Gasoline Pipeline

- Conventional pool fire radiation calculation, based on burning rate 0.067 kg/m<sup>2</sup>
- Pool fires calculated for impermeable/ waterlogged soil 100% diameter with probability of 50%, and 70%, and 70% diameter for average soil with 50% probability
- Wind tilt correlations for 5 m/sec wind to give thermal radiation distances to 14.7 kw/m<sup>2</sup> assuming 50% neutral to observer, 25% towards and 25% away from observer
- IMPACT - 100% fatal effects to persons in fire zone, either indoors or outdoor, and out to 14.7 kw/m<sup>2</sup>

## W S Atkins – Source of Ignition data

Fuel	No of Incidents	No of fires	Probability of Ignition
USA DOT Data			
Gasoline	284	10	3.5%
Jet Fuel	35	2	5.7%
Kerosene	9	0	0
All	328	12	3.7%
CONCAWE Data			
All	101	3	3.0%

## W S Atkins – Probability of Escape

- **Pool Fires** – “pool spreading is relatively slow – less than 1 metre/second in diameter, which should allow easy escape by walking away from a spreading pool at 2.5 m/sec. It is assumed that the fraction of people who suffer fatality within the affected area is about 10%.” NO – assume 100%
- **“Spray fires - assume 10% fatality in elliptical area”** NO – assume 100%

## 7 Source of Ignition Probability

For Land use Planning Zones assume:-

	Prob of Ignition	Prob of escape
Immediate Ignition Pool Fire	0.025	0
Delayed Ignition Pool Fire	0.025	0
Spray Fires (16% of total)	0.1	0
<b>Total</b>	<b>0.058</b>	

## 8 Scope for Site Specific Assessments for Gasoline Pipelines

- Pipeline characteristics – e.g.
  - Pipewall thickness – affects 3<sup>rd</sup> party failure rates
  - Risk mitigation measures – slabbing?, depth of cover? etc, – affects 3rd party failure rates
  - Pipe condition characteristics, OLI inspection results, - – affects mechanical / corrosion failure rates
- Ground characteristics
  - Sloping areas / Urban areas / Watercourses
- Usage characteristics
  - Flowrates /Actual pressures / Leak detection aspects
  - Proportion of time gasoline