Multi-Product Pipeline Network Quantified Risk Assessment

UKOPA Gasoline Meeting at OPA Offices London 12 February 2007

- Objectives

1. Describe methodology used for several UK pipelines
2. Describe areas of uncertainty – need your advice!
3. Describe possible HSE reaction / approach / objectives
4. Agree if we are on the right track – possible simplifications
5. Decide on next steps

Multi-Product Pipeline Network Quantified Risk Assessment

**UKOPA Gasoline Meeting at OPA Offices
London 12 February 2007**

- Acknowledgements to

1. CONCAWE / Peter Davis / Eric Martin
2. TOTAL – Robert White, FinaLine & Colnbrook
3. Esso and Esso Mainline – Dick Gray and Tony Taylor – their whole network
4. BP – Forties Line – Phil Hall
5. Ineos – Finnart Crude & M-P line – Neil Macnaughton
6. PIE

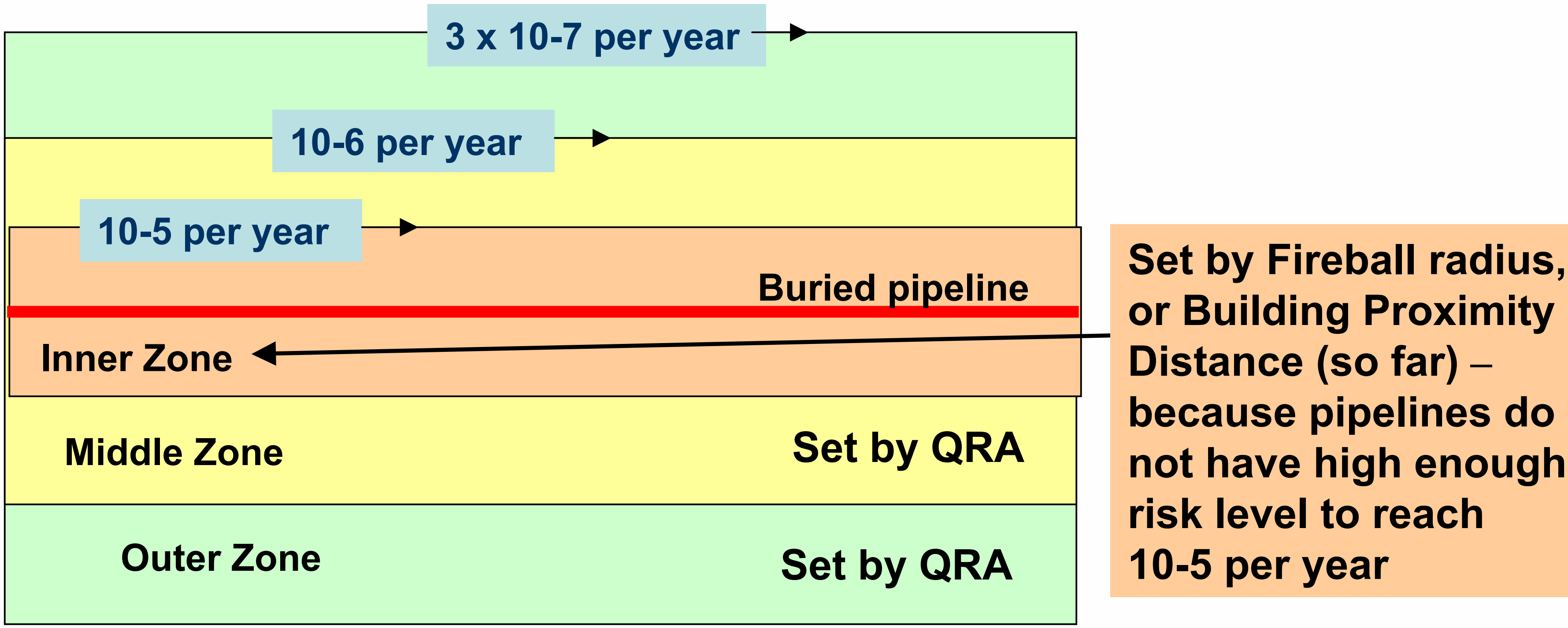
History / Background

- 5 key reports produced in 1990s, 3 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

- Reports analysed and discussed 25 November 2003
- Extensive limitations in 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
- Concerns expressed to HSE 10 December 2003 – no further HSE progress till April / May 2004

Land Use Planning Zones

- 3 zone Land Use Planning zones applied to Major Hazard Pipelines in late 1980s / early 1990s



Concerned with HOW THESE DISTANCES ARE DETERMINED, not what happens within these zones

- **Permitted developments in each zone described in HSE document PADHI – Planning Advice for Developments near Hazardous Installations**

The Sensitivity Levels are based on a clear rationale in order to allow progressively more severe restrictions to be imposed as the sensitivity of the proposed development increases. There are 4 sensitivity levels:

- Level 1 - Based on normal working population.
- Level 2 - Based on the general public - at home and involved in normal activities.
- Level 3 - Based on vulnerable members of the public (children, those with mobility difficulties or those unable to recognise physical danger).
- Level 4 - Large examples of Level 3 and large outdoor examples of Level 2.

Development Types are used as a direct indicator of the Sensitivity level of the population at the proposed development. Exceptions are made for some very large or very small developments by assigning them a higher or lower Sensitivity Level than normal for their Development Type.

The tables below expand on the four basic Development Types:

1- People at work, Parking
2 - Developments for use by the general public
3 - Developments for use by vulnerable people
4 - Very large and sensitive developments

PADHI Guidance

DT2.1 - HOUSING	Houses, flats, retirement flats/ bungalows, residential caravans, mobile homes.	Developments up to and including 30 dwelling units **and** at a density of no more than 40 per hectare – **Level 2**	Development where people live or are temporarily resident. It may be difficult to organise people in the event of an emergency.
	EXCLUSIONS		
	Infill, backland development.	**DT2.1 x1** Developments of 1 or 2 dwelling units - **Level 1**	Minimal increase in numbers at risk.
	Larger housing developments.	**DT2.1 x2** Larger developments for more than 30 dwelling units – **Level 3**	Substantial increase in numbers at risk.
		DT2.1 x3 Any developments (for more than 2 dwelling units) at a density of more than 40 dwelling units per hectare - **Level 3**	High-density developments.

Having determined which zone the development falls into and also the Sensitivity Level of the development, the following matrix is used to decide the type of advice.

Level of Sensitivity	Development in Inner Zone	Development in Middle Zone	Development in Outer Zone
1	DAA	DAA	DAA
2	AA	DAA	DAA
3	AA	AA	DAA
4	AA	AA	AA

DAA = **D**on't **A**dvise **A**gainst development.
AA = **A**dvise **A**gainst development.

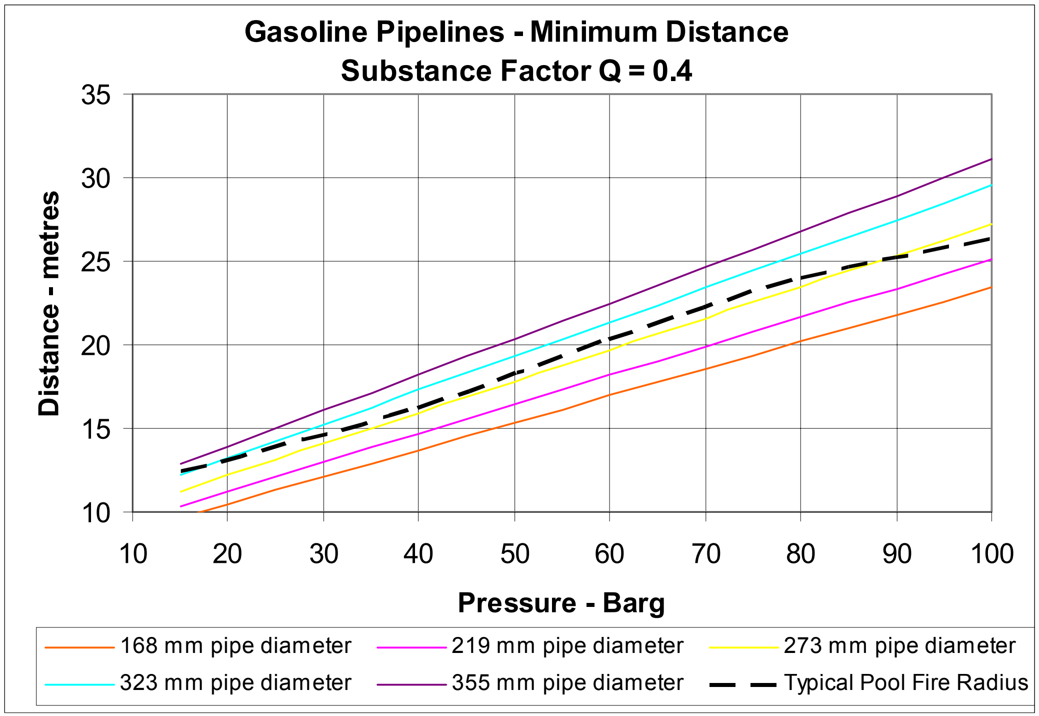
Inner Zone – how do we define Inner Zone for Gasoline Pipelines?

- Other substances – Fireball Radius (ethylene, spiked crude)
- 2001-2 – Natural gas pipelines – changes to Building Proximity Distance as defined by IGE/TD/1
- Indications from HSE – may use MDOB for PD 8010 substances would lead to a ~ small reduction for most pipelines
- MDOB (Minimum Distance to Occupied Buildings defined by

$$= Q\left(\frac{D^2}{32000} + \frac{D}{160} + 11\right) \quad \left(\frac{P}{32} + 1.4\right)$$

- Q is Substance Factor

For Gasoline, Pool Fire Radius can be correlated with pipeline diameter – dotted line shown below:-



Substance	Substance Factor Q
Ammonia	2.5
Ethylene	0.8
Hydrogen	0.45
Methane	0.55
LPG	1
NGL	1.25
Category C (oxygen etc.)	0.3

Using Substance Factor Q = 0.4 gives reasonable fit to pool fire radius

Resulting MDOB distances as shown:-

Pipeline Diameter		Pressure - Barg					
inches	mm	15	30	40	60	80	100
		Minimum Distance to Occupied Buildings - MDOB metres					
18	457	15	19	22	27	32	37
16	406	14	17	20	24	29	34
14	355	13	16	18	22	27	31
12	323	12	15	17	21	25	30
10	273	11	14	16	20	23	27
8	219	10	13	15	18	22	25
6	168	10	12	14	17	20	23

These could be applied as Inner Zone Distances

Suggest these are now incorporated into PD 8010?

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)

THIS COULD BE DIFFERENT FOR GASOLINE PIPELINES

- Maximum throughput more important than MAOP
- R & S Classification may be less significant (Design factor)
- ? Proportion of time gasoline in line
- ?? Leak detection

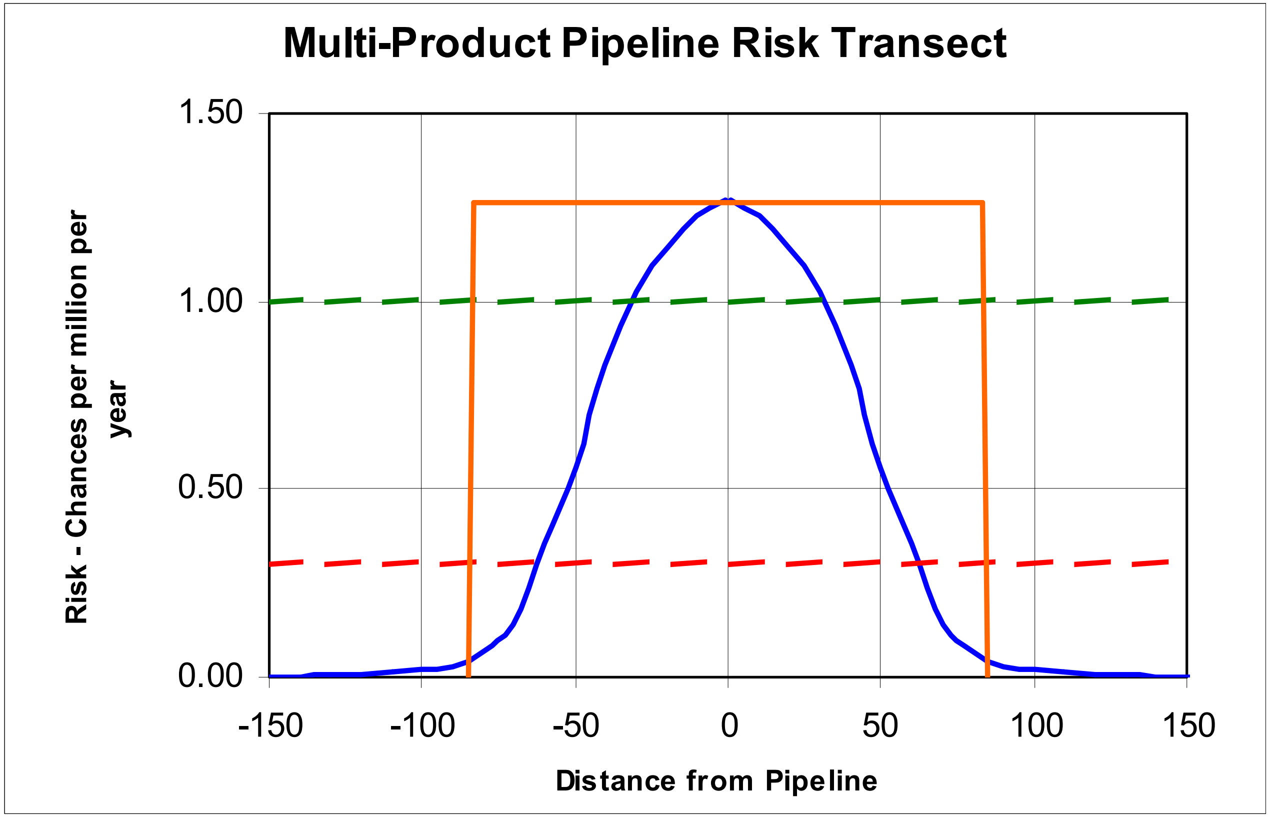
KEY PARAMETERS AFFECTING SAFETY RISK ASSESSMENT

- 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



Why make it complicated?

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

Basic Scenario is Pool Fire

Governed by Release rate:-

$$D_{max} = 2.\sqrt{m_r / \pi.m_f}$$

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^2 = 0.067 for large pool fires

Flow m3/hour	Diameter metres
200	28
300	34
400	40
500	44
1000	63
1500	77

However, other scenarios included to model actual events:-

Figure 1. Postaccident aerial view of portion of Whatcom Creek showing fire damage.

Delayed Ignition

Bellingham, near Seattle USA

About 3:28 p.m., Pacific daylight time, on June 10, 1999, a 16-inch-diameter steel pipeline owned by Olympic Pipe Line Company ruptured and released about 237,000 gallons of gasoline into a creek that flowed through Whatcom Falls Park in Bellingham, Washington.
About 1 1/2 hours after the rupture, the gasoline ignited and burned approximately 1 1/2 miles along the creek. Two 10-year-old boys and an 18-year-old young man died as a result of the accident. Eight additional injuries were documented.

A single-family residence and the city of Bellingham.s water treatment plant were severely damaged. As of January 2002, Olympic estimated that total property damages were at least $45 million.

Delayed Ignition Pool Fire

Typical 500 m3/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

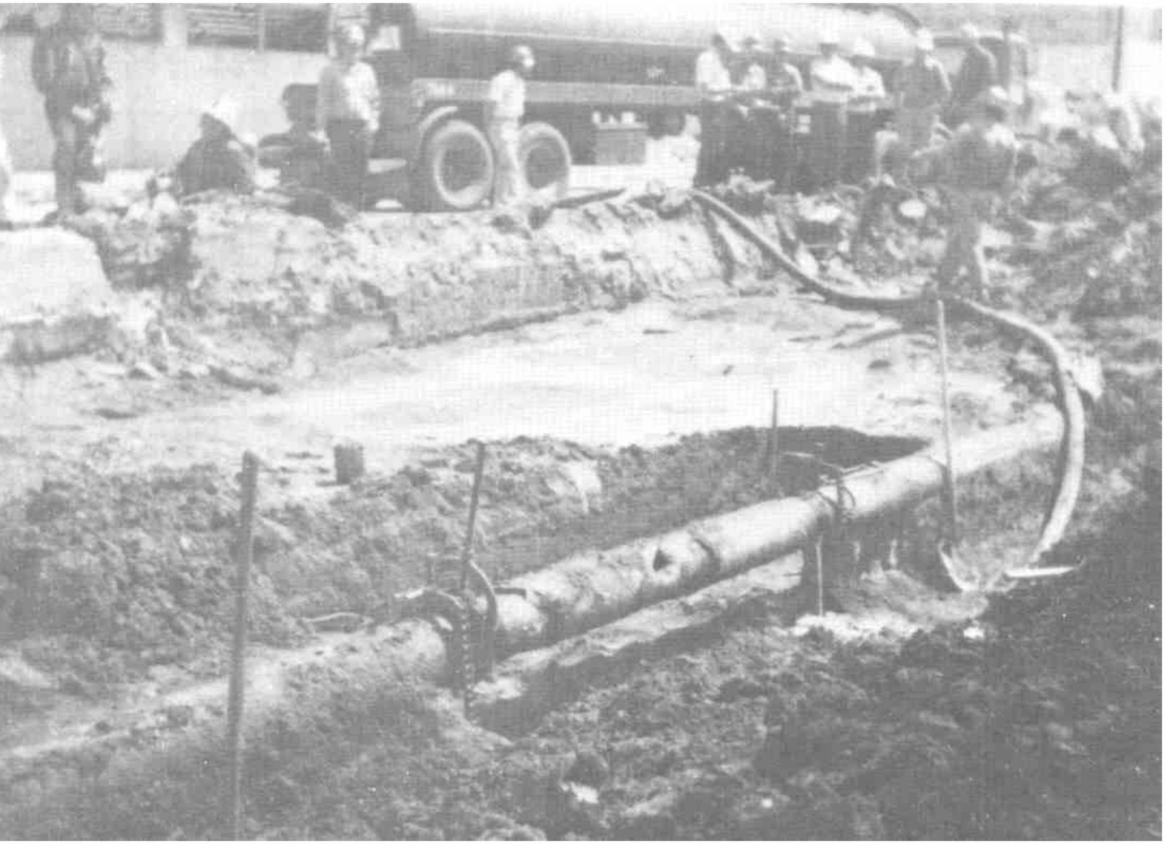
Reasonable to assume ignition probability increases with pool diameter

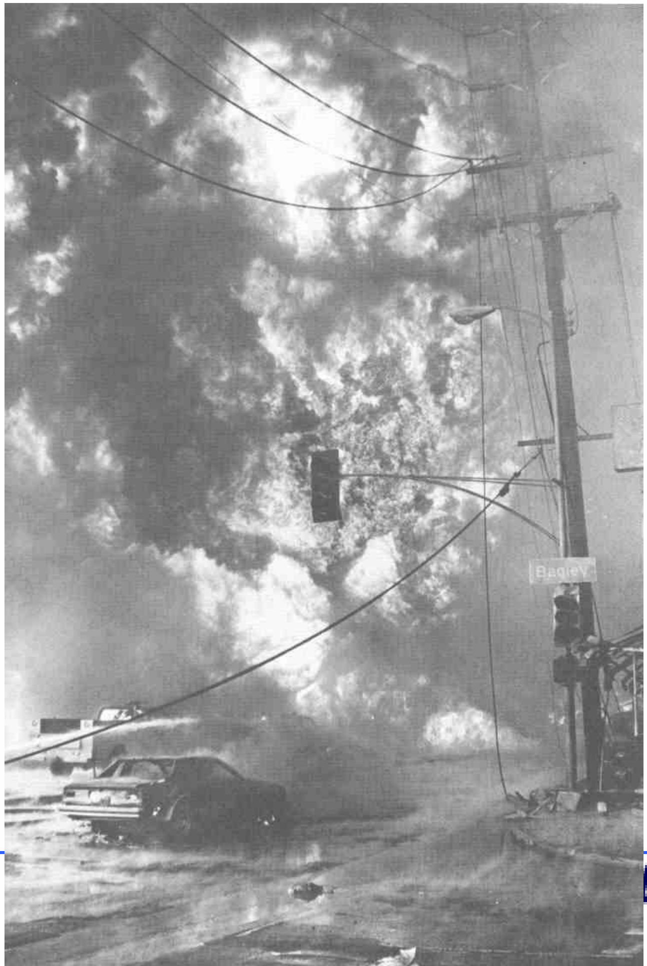
Therefore RISK LEVELS become dependent on

<u>speed of detection and shutoff</u>

Spray Fire - Los Angeles USA, 1976

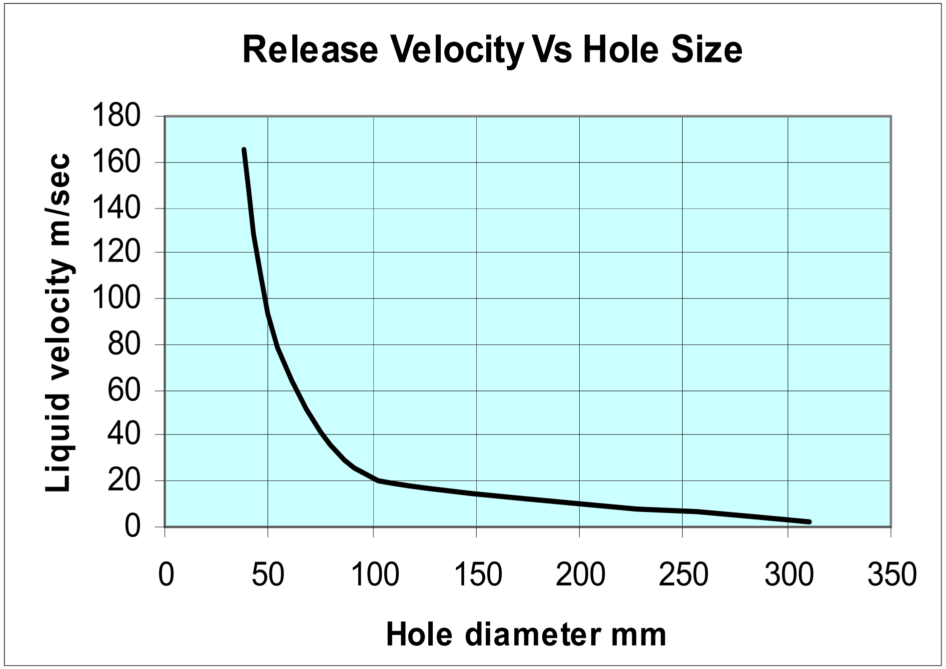
At 10.32 am on 16 June 1976, and 8 inch pipeline owned by Standard Oil Co was struck and ruptured by excavation equipment working on a road widening scheme. Gasoline sprayed from the rupture and sprayed nearby buildings. 90 seconds later the gasoline ignited, and the fire killed 9 persons, injured 14 and caused extensive property damage. Flow detection and alarms installed - alarmed at 10.32.12 and pump shutdown 3 minutes later at 10.35.28





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



- **Elliptical profile – small 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

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

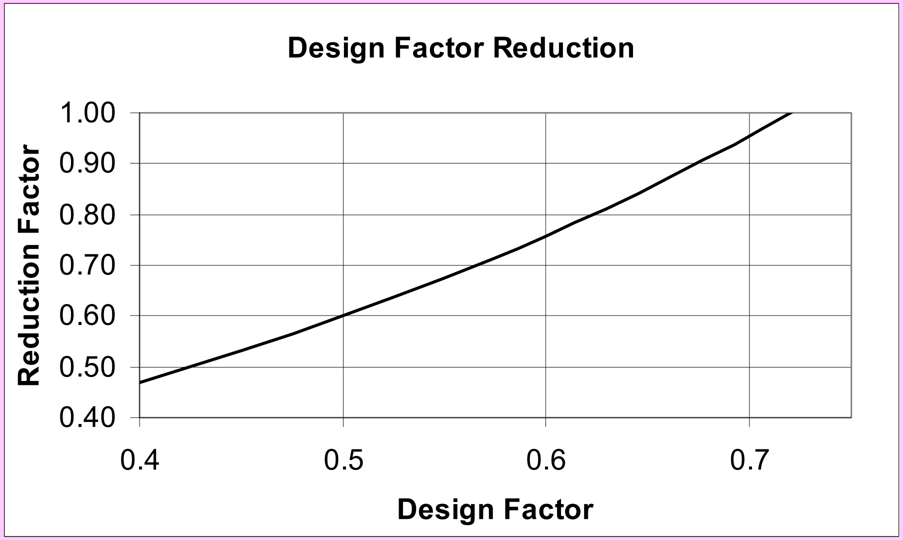
- Sent to HSE – no subsequent reaction of follow-up
- Need to develop data for use by HSE in PIPIN (their existing failure rates in PIPIN are suspect)

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
> Higher 3rd party
-At road crossings x 2
-Suburban areas x 4
(increased surveillance)
> Predictive modelling

Table 2 CONCAWE Leak Size Classification

-

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

Note hole sizes are based on amounts leaked out – therefore

Pinhole must not be interpreted as 25 mm hole size! –it would

Release 150 m3/hour – 4 minutes to leak out 10 m3

GENERIC FAILURE MECHANISMS

- 3rd Party interference / excavation
- Corrosion – internal and external
- Mechanical Defect – original or construction
- Natural Failure – earth movement / landslide etc.

UK Predictive failure rates Surveillance and 3rd party prevention procedures

Operator engineering and Maintenance procedures, OLI, CP, etc.

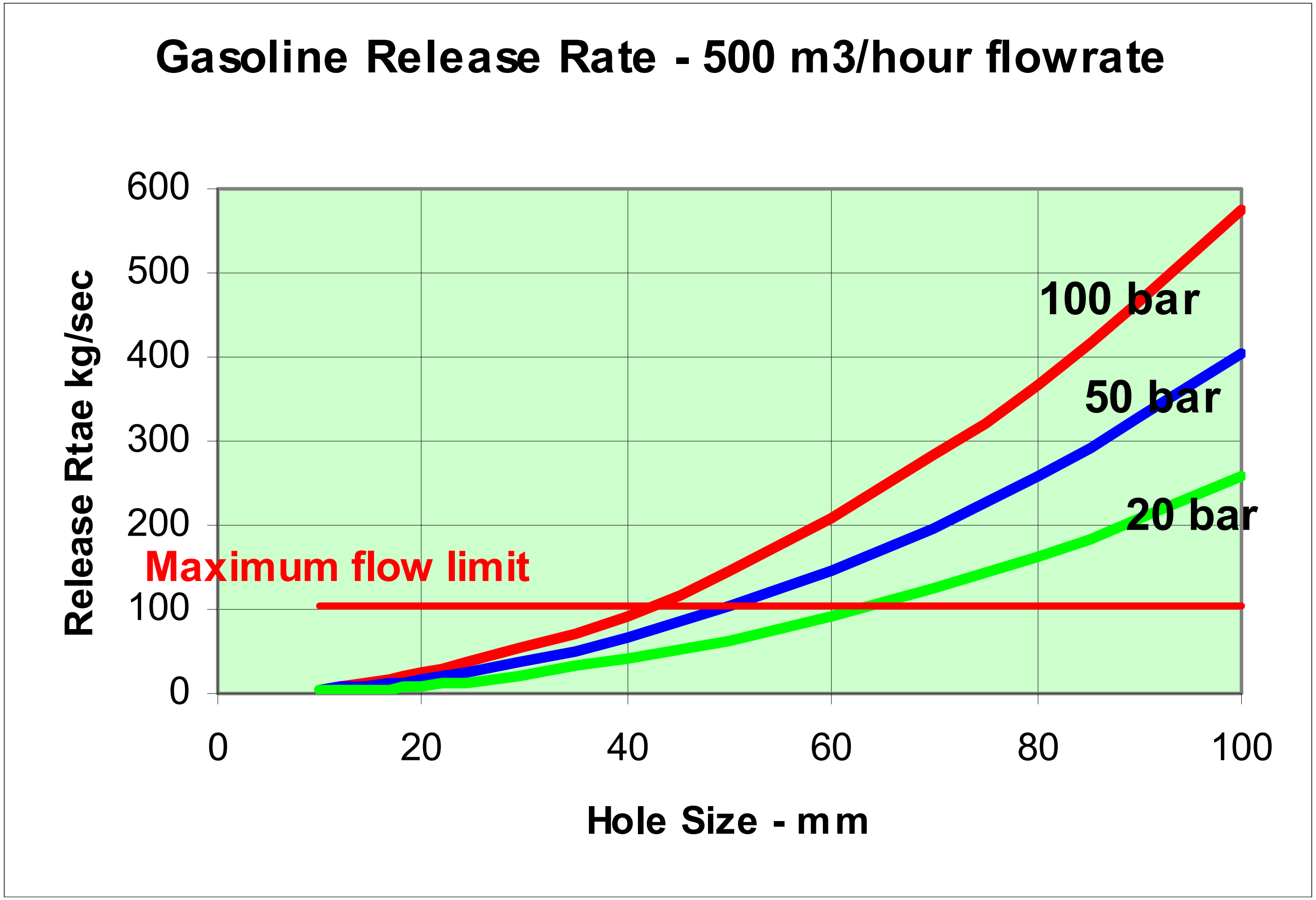
UK Natural Ground Movement Failure Rates

Good Design, Operating and Engineering Management Procedures, & Pipeline Integrity Monitoring

OPERATIONAL FAILURE MECHANISMS

- Overpressure - e.g. due to multiple pump operation
- Thermal Expansion
- Overpressure due to surge
- Fatigue due to pressure cycling

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

Small Hole	10 mm hole discharge rate
Puncture	Discharges full flowrate
Rupture	Discharges 110-120% flowrate due to pump rate increase with lower pipeline back-pressure

Proportion of time gasoline important because:-

- Kerosene / diesel / fuel oil have higher flash points (40^{o}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 allows for kero spray fire, but not usually a pool fire

DURATION OF RELEASE – affects delayed ignition pool size

- assessment from visit to Pipeline Control Centre
- manned control room
- good leak detection system
- alarms always active
- estimate 3 minutes to shut down system

Leak detection and Shutoff How long would it take?

- Is someone in the control room 100% of the time during pipeline transfers?
- Is the leak detection system switched on and working all the time?
- Do the operators have confidence in the leak detection system?
- Is there a unique and distinctive audible alarm on the leak detection system to immediately draw the operator's attention to the screens?
- Are there immediately available instructions as to what to do if the leak detection alarm occurs?
- Have the operators been trained in what to do if the leak detection alarm occurs?
- Are there simple and unambiguous instructions to shut down the pipeline if the leak detection alarm occurs?
- Is there a "no blame" culture which does not penalize the operator if he shuts down the pipeline and in fact there is no leak?
- Is there a direct button link in the control room to shut off the pumps or does someone have to be contacted at the terminal to shut off the pumps?

Amounts released to the Environment

Typical Amounts released in 3 minutes

Release Scenario	Release Rate from 10″ line in 3 minutes - m^3	Release Rate from 12″ line in 3 minutes - m^3	Release Rate from 16″ line in 3 minutes - m^3
Small hole	1.4	1.4	1.4
Puncture	15	25	36
Rupture	18	30	43

Typical Quantities Released Due to De-pressurisation

Length of Pipeline km	Diameter	Volume of Liquid in Pipeline m3	Volume Released on Depressurisation m3
100	16″	12,000	43
100	12″	6,300	24
100	8″	3,000	10

Typical Amounts Released due to Drain-Down

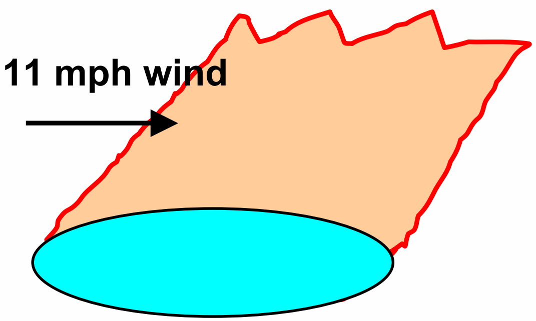
Drain Down Release Length - metres	Release from 10″ line m^3	Release from 12″ line m^3	Release from 16″ line m^3
100	5.3	7.6	12.2
1,000	53	76	122
10,000	530	760	1,220

Ground Soak-in

ATKINS suggest using 70% pool diameter for normal soil ground soak-in

Allowing for wet/satuated ground conditions, assume full pool size (no ground soak-in) for 50% of the time and

70% pool diameter for 50% of the time



Wind assumed to blow:-

25% of time towards observer

25% away

50% across

TOTAL of 8 fire cases for each hole size

Gasoline Pool Fires

Calculate Pool Fire

PipeRisk™

	Wet Ground Conditions			Dry Ground Conditions			Delayed 3 mins wet	Delayed 3 mins dry
Hole diameter	10 mm	Puncture	Rupture	10 mm	Puncture	Rupture		
Burning rate kg/s/m2	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067
Release rate into pool kg/sec	4.8	102.78	123.33	4.8	102.78	123.33		
Wind velocity - metres /second	5	5	5	5	5	5	5	5
Maximum Pool Diameter metres	9.5	44.2	48.4	6.7	30.9	33.9	48.3	33.8
Flame height with wind tilt	13.2	40.9	43.7	10.2	31.4	33.6	43.6	33.5
Flame tilt angle to vertical	54	41	39	56	44	43	40	43
Atmospheric humidity	50	50	50	70	70	70	70	70
Hazard distance wind neutral	**15.8**	**63.6**	**69.1**	**11.3**	**46.1**	**50.0**	**68.9**	**49.9**
Distance adjustment wind tilt	5.3	13.3	13.9	4.2	11.0	11.5	13.9	11.5
Hazard distance wind towards	**21.1**	**76.9**	**83.0**	**15.6**	**57.0**	**61.6**	**82.8**	**61.4**
Hazard distance wind away	**10.4**	**50.3**	**55.2**	**7.1**	**35.1**	**38.5**	**55.1**	**38.4**
Distance from poolfire	**11**	**42**	**45**	**8**	**31**	**33**	**45**	**33**
2.5 m/sec Running Escape Dose	**297**	**996**	**997**	**174**	**998**	**999**	**997**	**995**
Safe Distance for Escape	11	16.5	19.4	8	7.6	9.5	19.3	9.5
Thermal radiation KW/M2	25.7	25.6	25.6	25.7	25.7	25.6	25.7	25.7
Distance from poolfire	6.3	23.9	25.8	4.6	17.6	19.1	25.7	19
View Factor	0.288	0.314	0.316	0.282	0.308	0.309	0.316	0.309
Transmissivity of atmosphere	0.89	0.816	0.811	0.91	0.834	0.829	0.81	0.829
Thermal radiation KW/M2	14.8	14.7	14.7	14.8	14.7	14.7	14.7	14.7
Distance from poolfire	11.0	41.5	44.9	8.0	30.6	33.1	44.8	33.0

Distance to 14.7 kW/m2 used for 100% effect indoors and outside

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%."**
- **Spray fires -** assume 10% fatality in elliptical area

Release from Pipeline → Probability of Ignition → Fire → Probability of Escape → Serious injiury or Fatality

Possible to assess individual situations to assess both these probabilities:

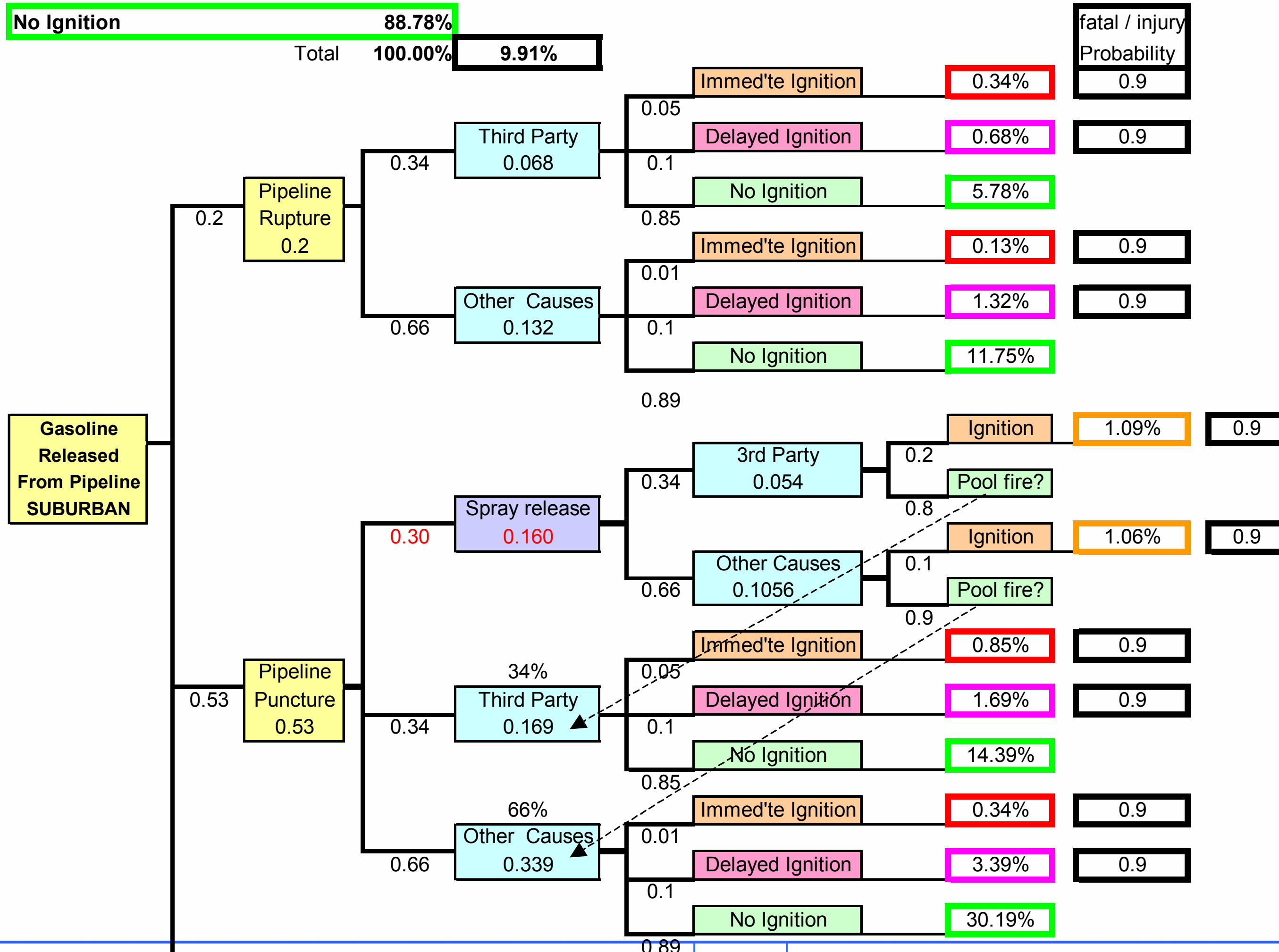
- very low for pool fires in rural conditions when cause is not 3rd party
- higher when cause is 3rd party
- higher when spreading pool might go into road areas or suburban
- higher for delayed ignition when spreading pool is larger (> 3 mins)
- higher for spray fires – especially in road and suburban areas
- low but possible for kerosene / diesel spray fires
- For specific risk assessments, (e.g actual pipeline conditions / locations) SUBJECT TO INDIVIDUAL CASE-SPECIFIC ASSESSMENT

Suburban Areas

Scenario	Probability of Ignition	Probability of Escape	Comments
Gasoline spray fire caused by 3rd party excavation	0.2	0.1	People in the vicinity carrying out excavation or in houses may cause ignition, and unlikely to be able to escape
Gasoline spray fire caused by other failures	0.1	0.1	People in houses may cause ignition, however people unlikely to be able to escape
Kerosene / others spray fire caused by 3rd party excavation & others	0.1 & 0.05	0.1	Lower probability (50%) of igniting kerosene / diesel spray / gasoil, same escape probability as gasoline
Gasoline immediate ignition pool fire caused by 3rd party excavation	0.05	0.1	People in the vicinity carrying out excavation or in houses may cause ignition, and unlikely to be able to escape
Gasoline immediate ignition pool fire due to other causes	0.01	0.1	People in houses may cause ignition, however people unlikely to be able to escape
Gasoline delayed ignition pool fire - all causes - 10 minutes delay to shutoff	0.1	0.1	People in houses may cause pool to ignite in the 10 minutes of full flow before pumps are shut off, however people in houses unlikely to be able to escape
Gasoline pool fires - small holes - probabilities reduced due to lower release rate and longer duration to form large pool	Lower by factor of 10	0.5 and 0.9	3rd party causing holes less likely to ignite release and able to warn people in the area, longer timescale to form pool and less likely to be ignited by other causes

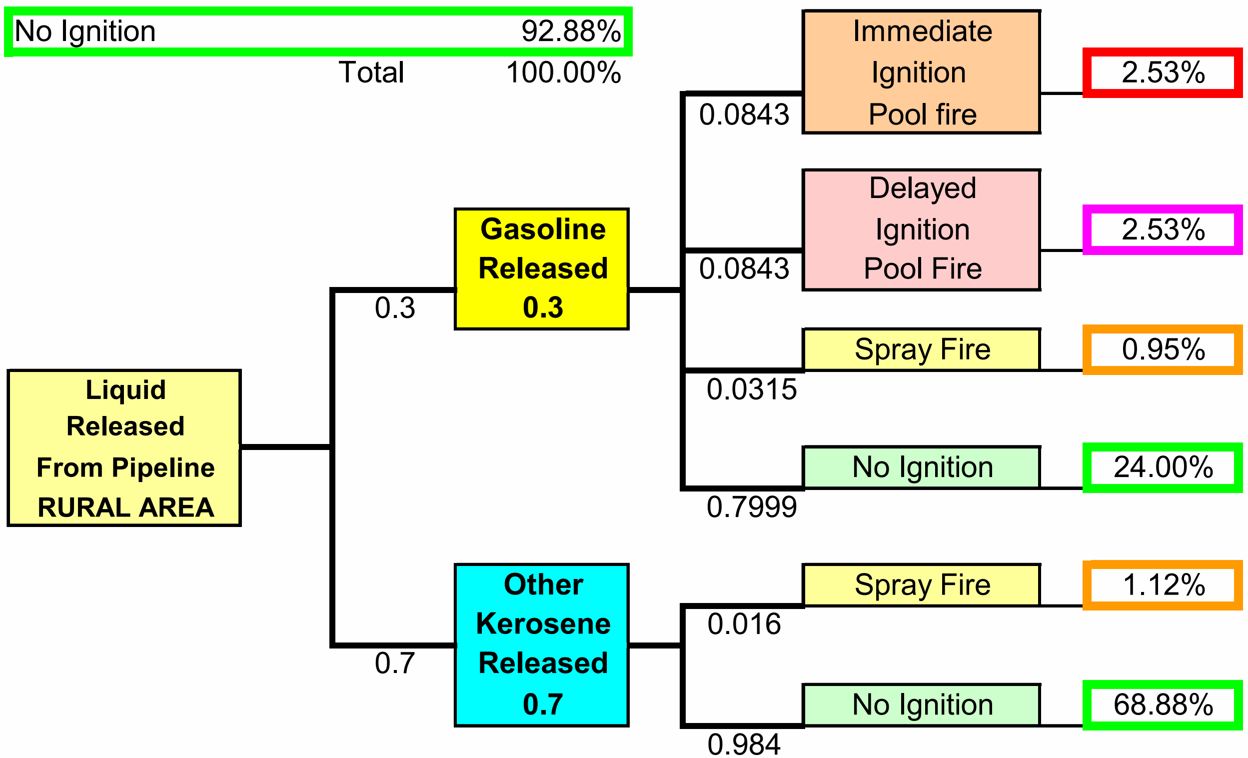
Multi-Product Pipeline - Probability of Ignition for Gasoline - Suburban areas

	Ignition	fatal/injury
Pool Fire Immediate Ignition	**1.72%**	**1.51%**
Pool Fire Delayed Ignition	**7.36%**	**6.48%**
Spray Fires	**2.14%**	**1.93%**
No Ignition	**88.78%**	
Total	**100.00%**	**9.91%**



Multi-Product Pipeline - Probability of Ignition - Suburban

Pool Fire Immediate Ignition	2.53%
Pool Fire Delayed Ignition	2.53%
Spray Fires	2.07%
No Ignition	92.88%
Total	100.00%



QRAs carried out so far for:-

SUBURBAN - 4 times 3rd party failure rate AND higher probabilities of ignition

ROAD CROSSINGS – 2 times 3rd party and intermediate probabilities of ignition

RURAL - No increase in 3rd party failure rate, low probabilities of ignition

RURAL and ROAD Crossings usually show NO MIDDLE ZONE

What happens when there is no Middle Zone?

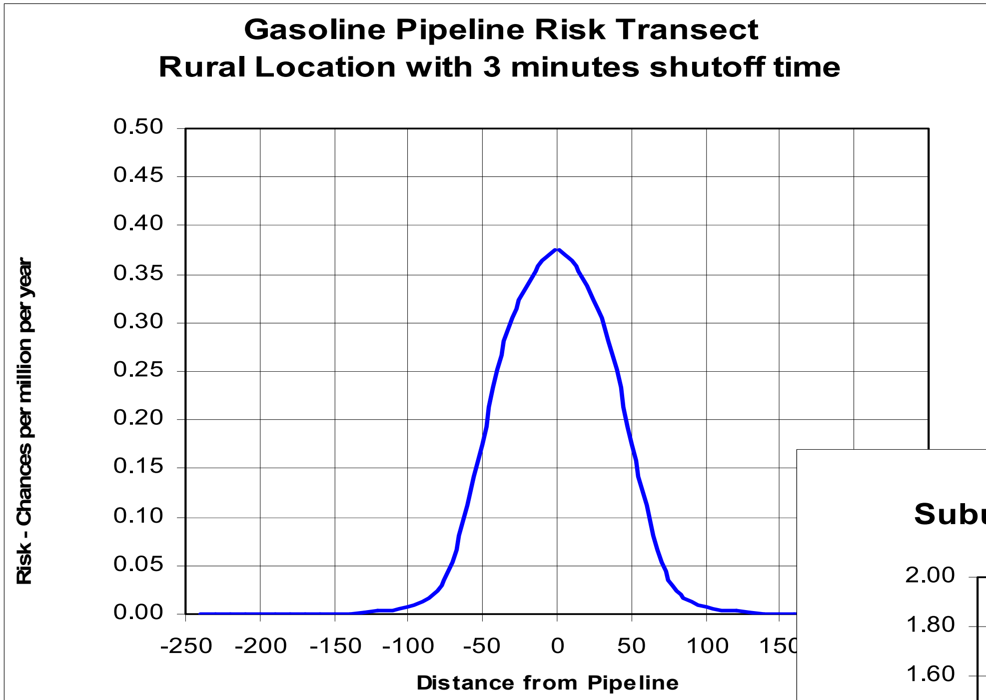
Result show smaller (in some cases no) Middle Zone and smaller Outer zones

In such Cases, HSE apply Inner Zone Distance to Middle (and Outer) Zone:-

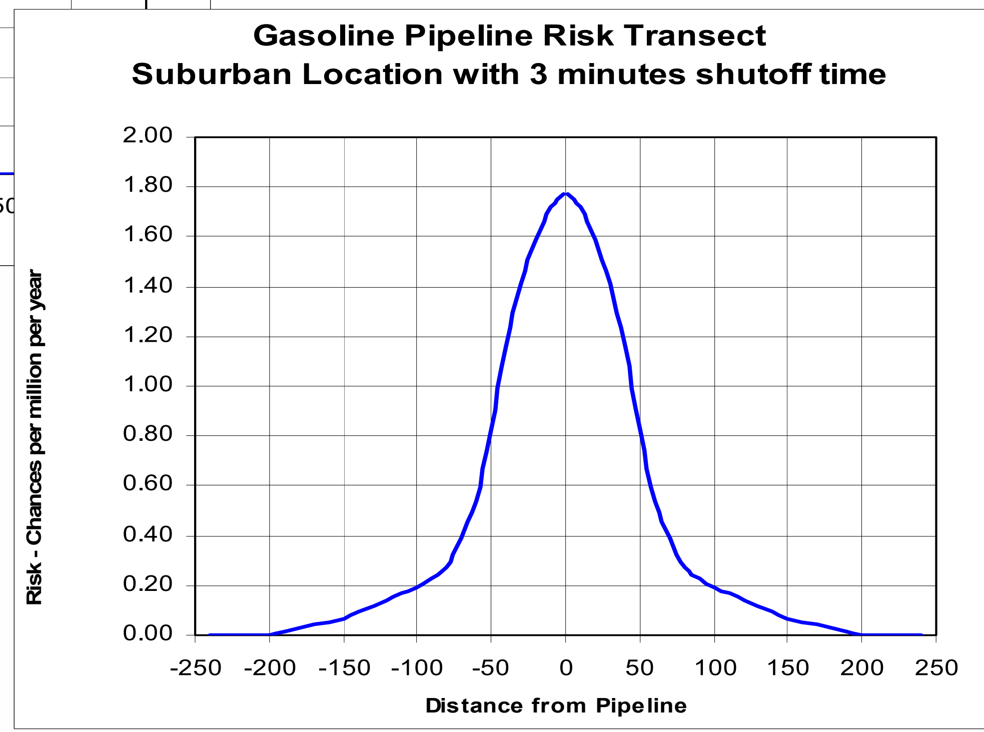
For example
Calculation gives Inner 0, Middle 0, Outer 45 metres, MDOB 25 metres

Zones would be Inner 25, Middle 25, Outer 45

Results from Actual QRAs:



**36%
GASOLINE
RURAL**



**20%
GASOLINE
SUBURBAN**

Land Use Planning Zones – HSE application

- HSE typically apply a set of zones for the whole pipeline
- There are very few true "thick-wall cases" – I.e. wall thickness greater than 11.91 mm and Design Factor < 0.3 [will re-classification of gasoline under PD 8010 require "thick wall" in suburban areas]
- Therefore thicker wall cases (e.g. road crossings)do not change LUP zones substantially
- For such cases, Case Specific calculations required if planning applications arise.
- Which set of Source of Ignition (SOI) probabilities to apply? RURAL ROAD CROSSINGS, SUBURBAN?
- HSE conservatively apply high SOI because future development represents higher SOI when it is built
- Therefore may have to accept SUBURBAN zones in RURAL areas?

For **Land Use Planning purposes**, a simpler application may be:-

1 assume 100% gasoline occupacity, but use historical
Source of Igntion probabilities:-

Spray fire 3rd party	= 0.1
Spray fire other causes	= 0.05
Immediate Ignition pool fires	= 0.025
Delayed Ignition pool fires	= 0.025

2 Assume Probability of harmful effects = 1 (no escape)

3 Assume leak detection and shutoff time of 5 minutes

4 3rd party failure rates for suburban areas

Typical results:-

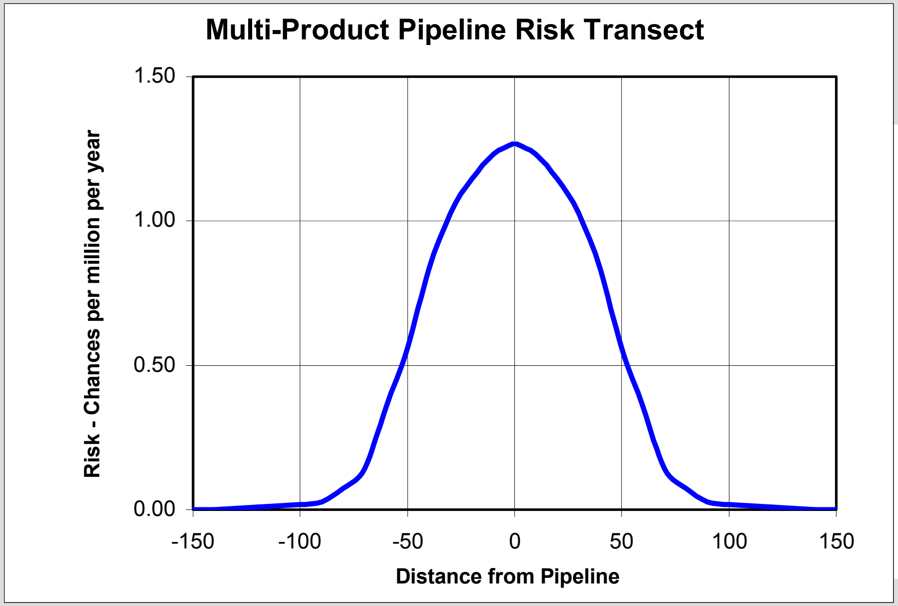
PipeRisk™

Gasoline Pipeline Risk Assessment

Multi-Product Pipeline 69 bar

Calculate

Pipeline Diameter	mm	323.9
Pipeline Wall Thckness	mm	8.4
Pipeline MAOP	barg	69
Pipeline Length	km	92
Maximum Flowrate	m3	500
Proportion of time Gasoline	%	100%
Probability at this pressure	%	100%
Emergency shutoff time	mins	5



MDOB 23

5 minutes shutoff time	
Inner Zone 10-5	0
Middle Zone to 10-6	32
Outer Zone to 3 x 10-7	63

Contribution to risk with distance from pipeline

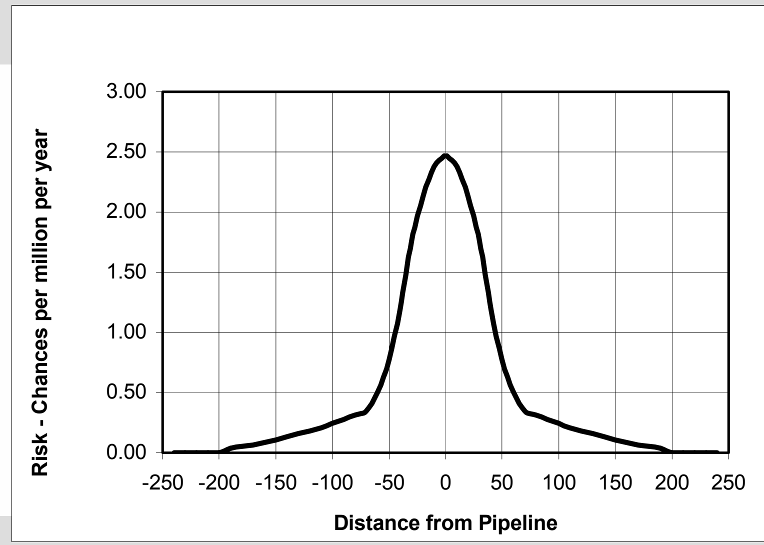
Percent risk centreline	10	20	30	40	50	60	70	80	90
Spray Fires									
9.7%	9.5%	9.3%	9.0%	9.6%	12.2%	15.9%	31.2%	49.1%	100.0%
Immediate Pool Fires									
46.2%	45.8%	44.9%	44.7%	43.9%	41.8%	38.2%	32.0%	16.2%	0.0%
Delayed Pool Fires									
44.1%	44.7%	45.8%	46.3%	46.5%	46.0%	45.9%	36.8%	34.6%	0.0%

PipeRisk™

Gasoline Pipeline Risk Assessment

Multi-Product Pipeline 114 bar

Pipeline Diameter	mm	273
Pipeline Wall Thckness	mm	6.4
Pipeline MAOP	barg	114
Pipeline Length	km	233
Maximum Flowrate	m3	362
Proportion of time Gasoline	%	100%
Probability at this pressure	%	100%
Emergency shutoff time	mins	5



10 minutes shutoff time	
Inner Zone 10-5	0
Middle Zone to 10-6	46
Outer Zone to 3 x 10-7	85

MDOB 30

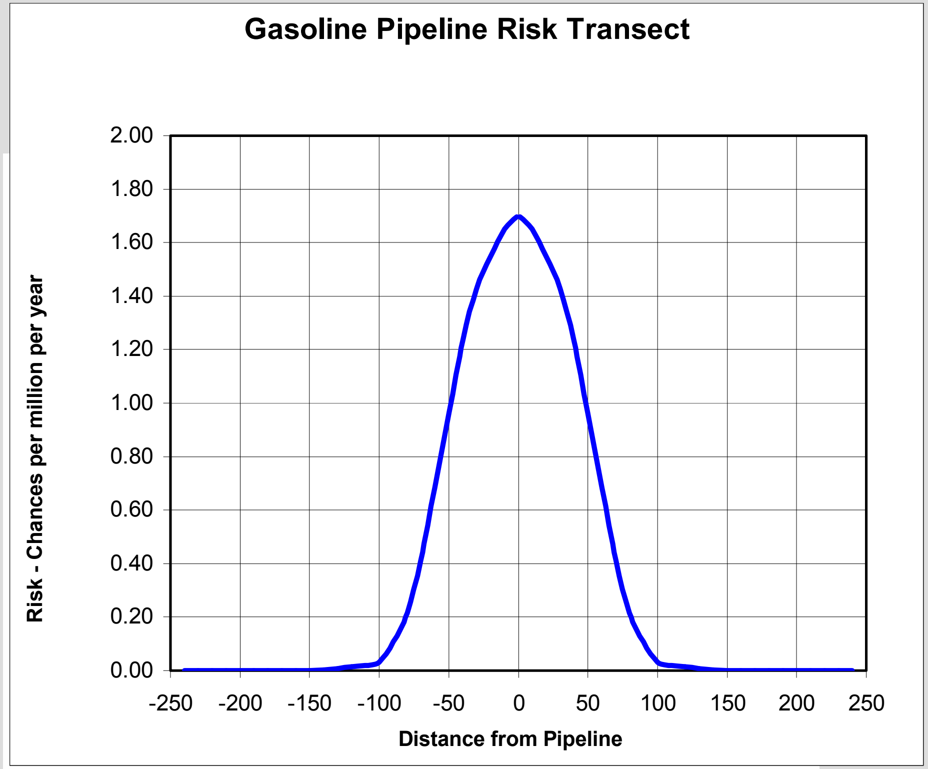
Gasoline Pipeline Risk Assessment

Suburban

Pipeline Diameter	mm	406.4
Pipeline Wall Thckness	mm	9.52
Pipeline MAOP	barg	71
Design Factor Reduction		0.42
Rural / Suburban Factor		4
Pipeline Length	km	200
Maximum Flowrate	m3	680
Proportion of time Gasoline	%	100%
Emergency shutoff time	mins	5

Calculate

MDOB 27

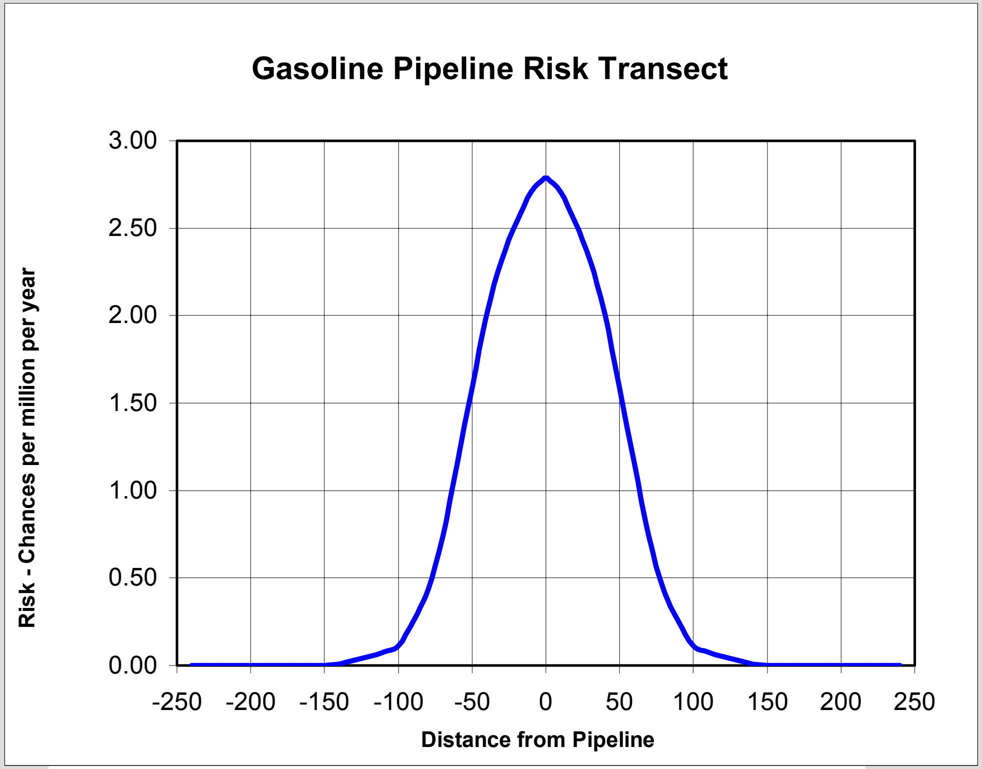


3 minute shutoff time	
Inner Zone 10-5	0
Middle Zone to 10-6	49
Outer Zone to 3 x 10-7	76

Gasoline Pipeline Risk Assessment

Calculate

Pipeline Diameter	mm	323.9
Pipeline Wall Thckness	mm	6.35
Pipeline MAOP	barg	71.6
Design Factor Reduction		0.72
Rural / Suburban Factor		4
Pipeline Length	km	45
Maximum Flowrate	m3	680
Proportion of time Gasoline	%	100%
Emergency shutoff time	mins	5



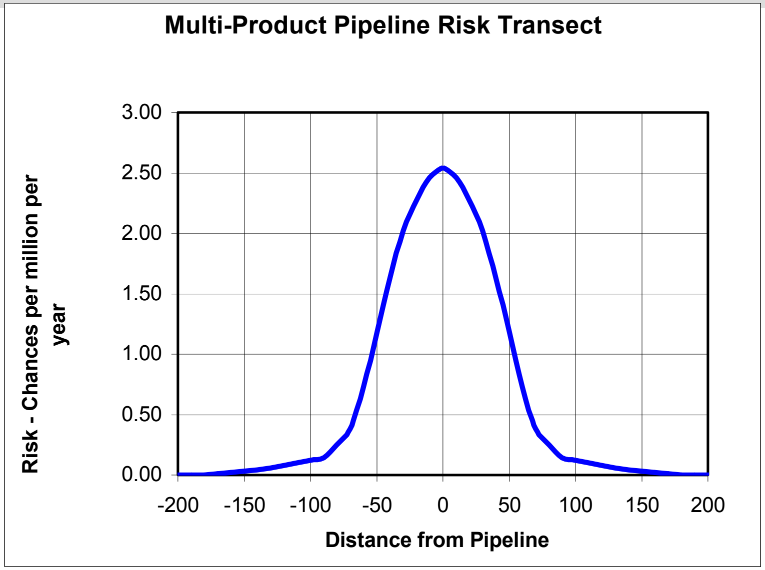
MDOB 24

5 minute shutoff time	
Inner Zone 10-5	0
Middle Zone to 10-6	63
Outer Zone to 3 x 10-7	85

Gasoline Pipeline Risk Assessment

Calculate

Pipeline Diameter	mm	355.6
Pipeline Wall Thckness	mm	5.6
Pipeline MAOP	barg	88.5
Design Factor Reduction		0.89
Rural / Suburban Factor		4
Pipeline Length	km	150
Maximum Flowrate	m3	470
Proportion of time Gasoline	%	100%
Emergency shutoff time	mins	5



MDOB 29

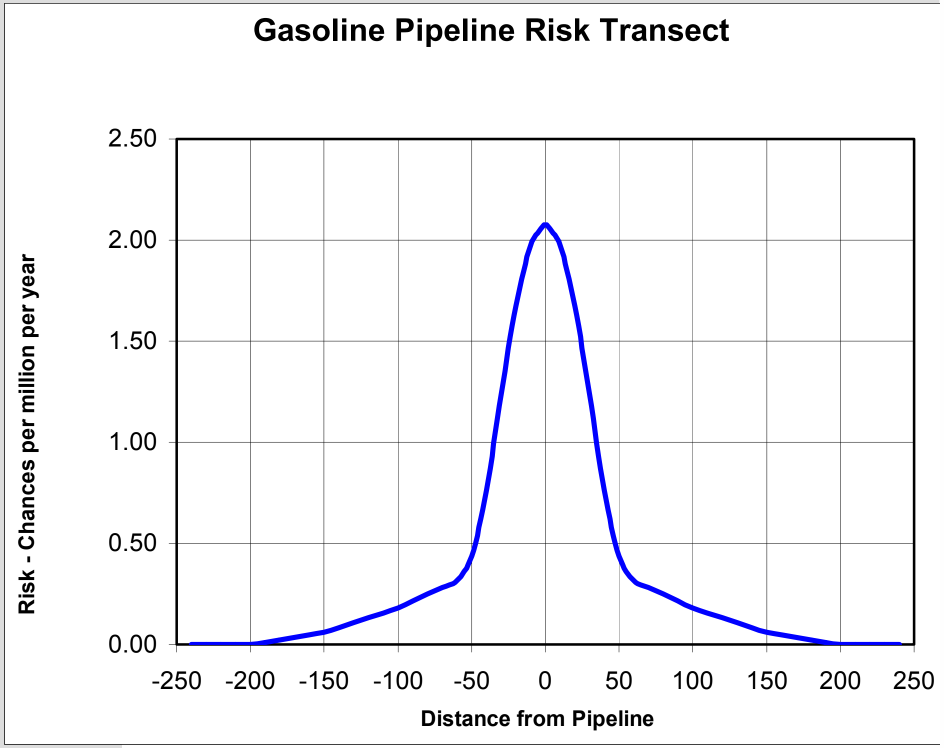
3 minute shutoff time	
Inner Zone 10-5	0
Middle Zone to 10-6	53
Outer Zone to 3 x 10-7	76

Gasoline Pipeline Risk Assessment

Calculate

Input Data

Pipeline Inlet Pressure	barg	99.3
Pipeline Length	km	133
Pipeline diameter	mm	158.8
Maximum Flowrate	m3	180
Proportion of time Gasoline	%	100%
Emergency shutoff time	mins	5



MDOB 23

5 minute shutoff time	
Inner Zone 10-5	0
Middle Zone to 10-6	35
Outer Zone to 3 x 10-7	65

CONCLUSIONS from the Safety Study

1. QRA of several pipelines completed
2. Failure rate data for generic causes - CONCAWE data,
3. Analysis of release rates - hole sizes in excess of ~ 50 mm release full normal flow
   Therefore use of MAOP does not make much difference
4. Higher probabilities of ignition for gasoline - Therefore proportion of time in gasoline is important
5. Four consequences analysed based on W S Atkins 1998
6. Analysis of leak detection system + discussions with control staff
   = shutoff time will be less than 3 minutes.
   This time is important for safety analysis and for environmental impact
7. Large volume of hydrocarbon liquid at pressure will result in significant liquid release due to compressibility
8. General approach suggests that the levels of risk are low as predicted in this study
9. Suggested MDOB presented
10. Used same SOI data for crude oil as for gasoline

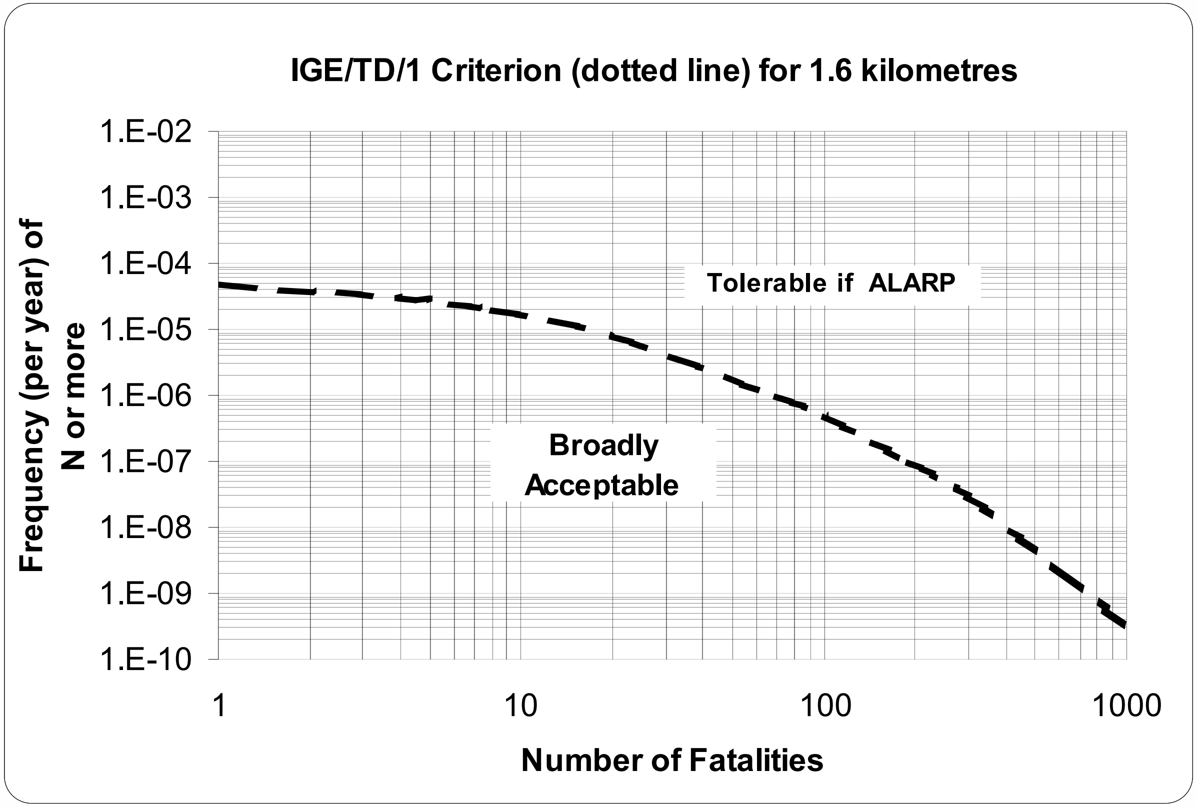
Issues with HSE

1. PIPIN – different (more pessimistic) interpretation of CONCAWE
2. Modification to CONCAWE data for UK conditions
3. Predictive modelling for 3rd party
4. Reduced UK ground movement failure frequencies
5. Reduced mechanical / corrosion failure rates for UK
6. Notification details – effects of maximum flow rather than MAOP
7. Acceptance of
    1. Duration on gasoline service
    2. Source of ignition data
    3. Delayed ignition pool fires and leak detection
    4. Atkins modelling for spray fires and dry earth conditions
8. Use of Rural or Suburban failure frequencies and SOI probabilities for setting standard Land Use Planning Zones

Implications of Development of PD8010

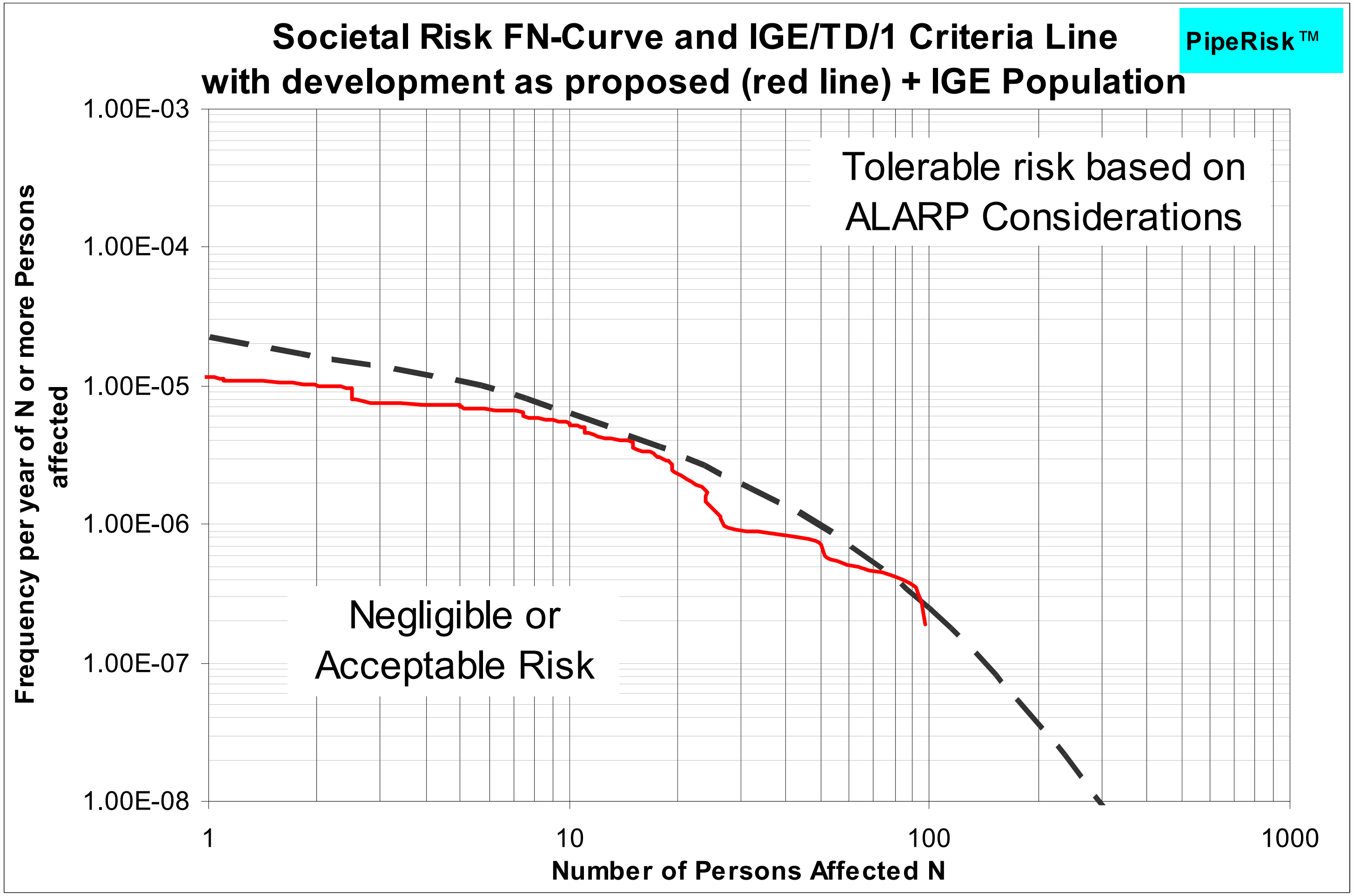
1 Requirement to provide thick-wall pipe in suburban areas?

2 Possible inclusion of Societal risk assessment to assess population increase during life of pipeline

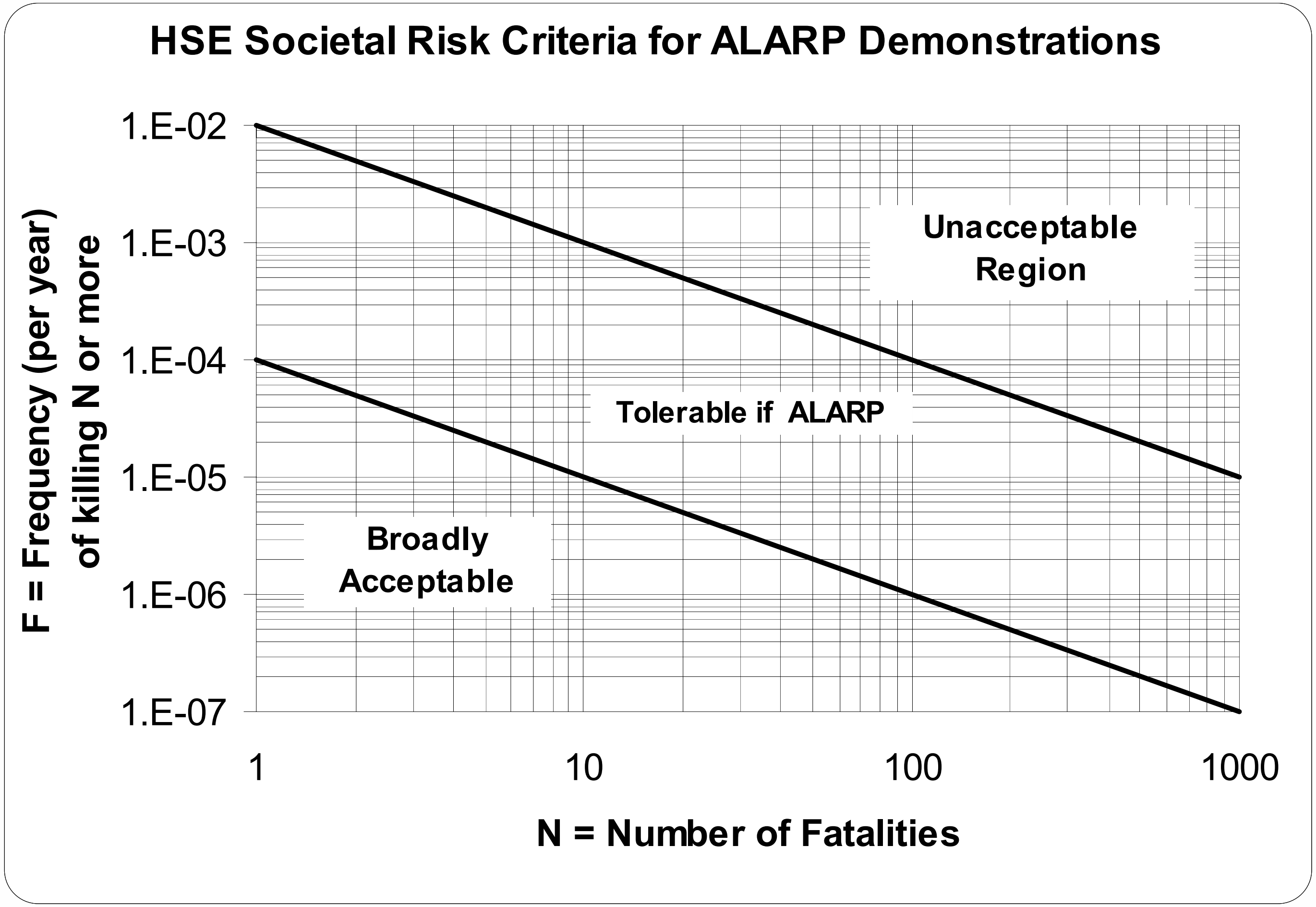


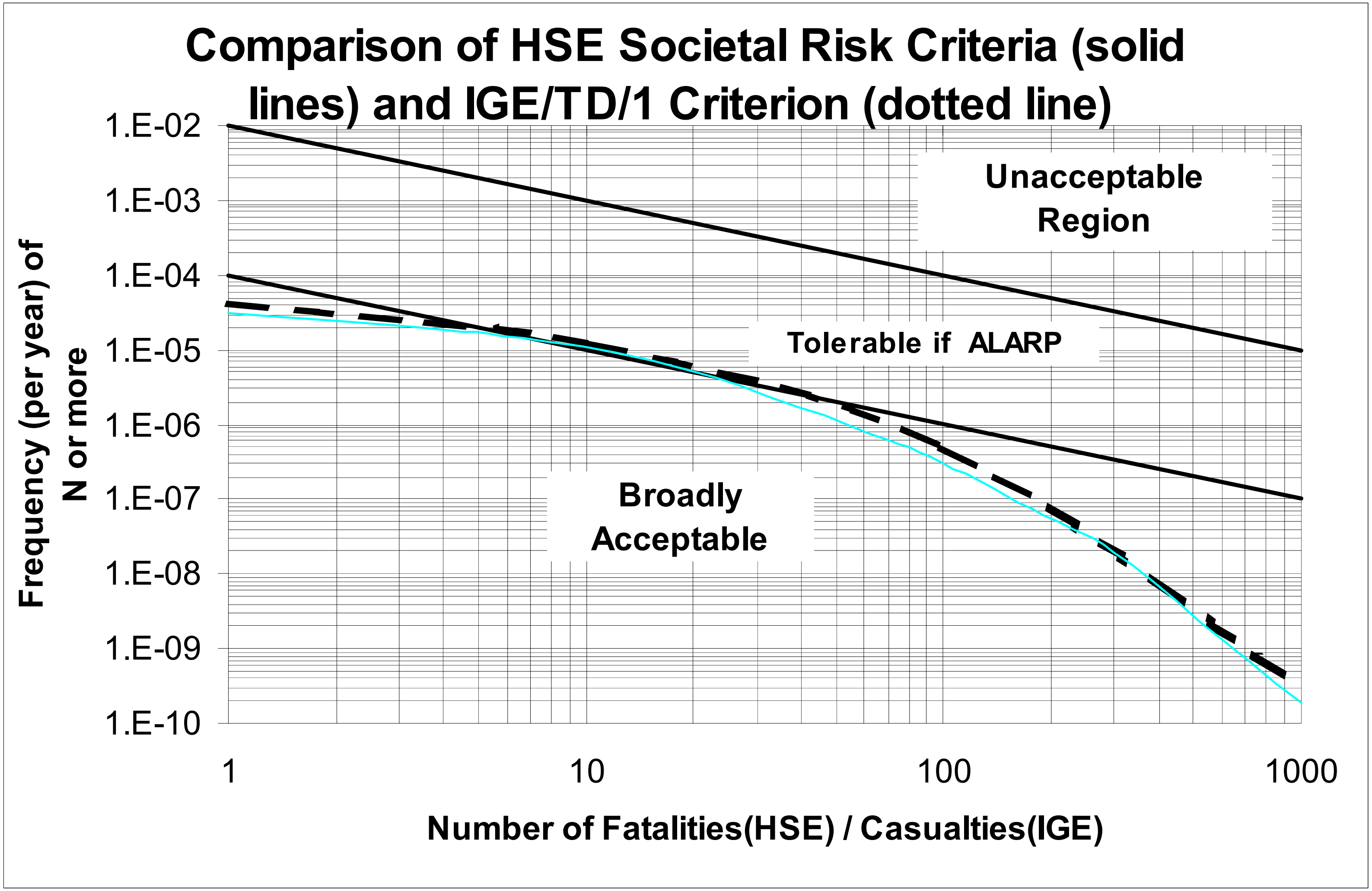
- Currently published In IGE/TD/1
- Used by National Grid to assess population increases in specific areas
- Possible risk reduction required in some cases

Example to be included in IGE/TD/1 Code supplement:-



Now withdrawn COMAH ALARP demonstration curves:-





For higher numbers occurring due to flash fire / extended effect compared to natural gas – need straight line FN Curve

Proposed curve to go into the PD8010 Code Supplement:-