2nd UKOPA Technical Seminar

"Managing the Risk from Pipelines Containing Hazardous Fluids"

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Developments in Land Use Planning and the application of Risk Assessments

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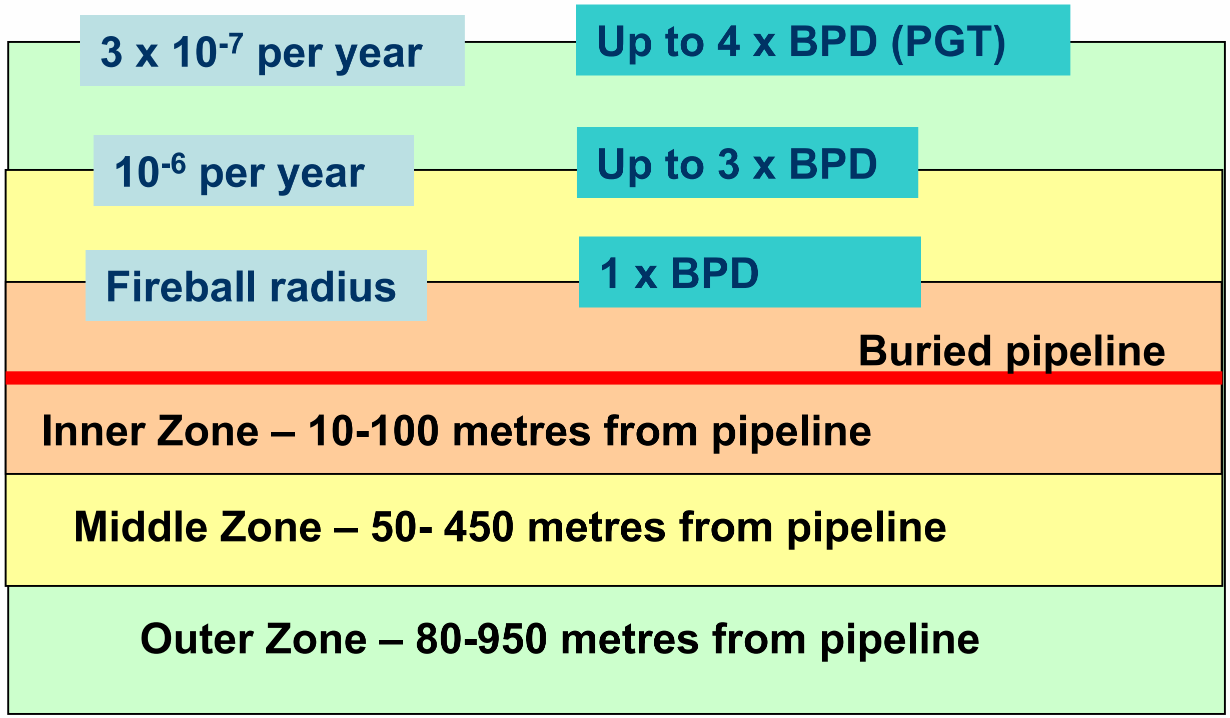
Pipeline Land Use Planning Zones

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



- One of UKOPA's main interest has been in the <u>SIZE of the LUP Zones</u>

How are pipeline failure risks quantified?

Risk Assessment Studies

- **Hazard Identification** *- what can happen?*
  - External Impact, Corrosion
  - Mechanical defect, Natural / ground movement
  - Other, Operational, Rupture, Puncture, Pinhole
- **Frequency Analysis** - how often?
  - Incident Data - Historical
  - Fault data - extrapolation
  - Predictive Modelling, Fracture Mechanics
- **Consequence Analysis** *- how bad?*
  - Release - leak rate, rain out
  - Dispersion
    - Gas jet / plume
    - Pool Evaporation
    - Wind/ Weather
  - Effects
    - Fire Radiation
    - Explosion Overpressure
    - Toxic Effects
- **Risk Tolerability** *- is it OK?*
  - Individual Risk / Transects / Societal Risk Criteria / Land Use Planning Zones

- **Early 1990s – Land Use Planning Issues became a problem**
- **Several outline planning applications withdrawn when presence of pipeline was discovered and HSE Advised Against**
- **Pipeline operator contacted…..**
- **British Gas / Transco QRA-based assessments – during mid-1990s Joint Programme of Work set up with HSE to generate risk-based zones:-**

David Eves, Deputy Director General of the HSE

to British Gas, 24 August 1995:-

"Let me assure you that HSE remains committed to the development of a risk-based approach for the provision of land-use planning advice".

ICI Chemicals & Polymers Limited
Teesside Operations
Safety Group
Wilton

6 August 1993

MEETING WITH BRITISH GAS TO DISCUSS RISK ASSESSMENT APPLIED TO PLANNING APPLICATIONS NEAR UNDERGROUND PIPELINES

Present:-

Phil Jones - British Gas Transmission Group, Solihull
Mike G Dodson - Safety Engineering Group, Hinckley
K E Thomas - TPEP Pipeline Superintendent
R A McConnell

The purpose of the meeting was to share experience of problems with planning applications which are refused on advice from HSE due to their proximity to high pressure gas pipelines. Recent experience with the Trans-Pennine Ethylene Pipeline has highlighted the need to have a definitive understanding of the HSE's stance.

- **1996-97 - UKOPA formed,**
- **Risk Assessment Work Group established – HSE included**
- **Leak and Fault data pooled through BG Technology (Advantica) to generate the UKOPA Fault Database – first report published 2001**
  - HSE are participating members
- **2001 Working Group on Pipelines (WGP) formed – UKOPA + HSE members, chaired by Prof Gordon Walker - member of ACDS**
- **HSE developed risk-based LUP zones generated by HSE for all PGT (Transco) pipelines - *including "S" area (suburban) pipelines***
- **UKOPA involvement through the Working Party (Risk Assessment) sub-group of WGP – helped the risk-based approach to be developed**
- **2005 – 2008, UKOPA developed Code Supplements outlining key aspects of QRA as applied to site specific Land Use Planning cases**

HSE have shared their thinking and modelling with UKOPA at various joint meetings and seminars:-

Factors Involved in the Application of Risk Assessment to Natural Gas Pipelines

Proposals for a Risk Based Siting Policy for "Rural" Pipelines

HSE Pipeline Risk Assessment

- Progress Since Last Workshop
  - Initial Risk Results for BG's Network
  - Refinement of Failure Probabilities
    - Partial use of UKOPA data
  - Current Position

Major Hazard Pipelines: HSE'S APPROACH TO LAND USE PLANNING ADVICE

Failure Frequencies

	Rupture	Large Hole	Small Hole	Pin Hole
Third Party	PIPIN Predictive Model	PIPIN Predictive Model	PIPIN Predictive Model	PIPIN Predictive Model
Mechanical	8.10^{-12}	8.10^{-12}	2.10^{-11}	9.10^{-8}
Natural	2.10^{-9}	2.10^{-10}	2.10^{-9}	6.10^{-9}
Corrosion	EGIG Data via PIPIN	EGIG Data via PIPIN	EGIG Data via PIPIN	EGIG Data via PIPIN
[illegible]	[illegible]	[illegible]	[illegible]	3.10^{-8}

HSE Pipeline Risk Assessment

- Future Work
  - HSE/UKOPA collaboration to produce a single UK failure model?
    - Common input data distributions for predictive TPA models
    - Agreed and justified treatment of Natural and Corrosion failures
    - Agreed and justified treatment of Mechanical failures
      - Is there scope for a predictive model?

WGP/02/0008

HSE Gasoline Pipeline

Risk Assessment Methodology

April 1999

Over the years, HSE have published their methodology….

Full Papers

Aspects of risk assessment for hazardous pipelines containing flammable substances

David A. Carter
Major Hazards Assessment Unit, Health & Safety Executive, St Anne's House, University Road, Bootle, Merseyside L20 3MF, UK*

Pipes & Pipelines *International* March-April 199

Risk calculation for pipelines applied within the MISHAP HSE computer program

by Mike Bilo[1] and Dr Peter Kinsman[2]
[1]HM Specialist Inspector, Major Hazards Assessment Unit, Health & Safety Executive, Bootle, UK
[2]MechPhyic Scientific Consultants, Tarvin, Chester, UK

Pipes & Pipelines *International* July-August 1997

MISHAP - HSE's pipeline risk-assessment methodology

by Mike Bilo[1], and Dr Peter Kinsman[2]
[1]HM Specialist Inspector, Major Hazards Assessment Unit, Health & Safety Executive, Bootle, UK

4. FLASHING-LIQUID FLOW CALCULATIONS FOR USE IN RISK ASSESSMENT

by
Mr. D. A. Carter
Health & Safety Executive*

The views expressed in this paper are those of the author and not necessarily those of the HSE.

Pipes & Pipelines *International* November-December 1997

Thermal radiation criteria used in pipeline risk assessment

by Mike Bilo[1] and Dr Peter R.Kinsman[2]
[1]Major Hazards Assessment Unit, Health & Safety Executive, Bootle, UK
[2]Mech-Phyic, Tarvin, Chester, UK

PIPELINES PROTECTION - HOW PROTECTIVE MEASURES CAN INFLUENCE A RISK ASSESSMENT OF PIPELINES

DAVID A JONES AND TIMOTHY GYE
Major Hazards Assessment Unit
Health and Safety Executive *
St Anne's House, University Road, Bootle, Merseyside L20 3MF, UK

HSE documented their methodology which became available through Freedom of Information:-

schp_06c – (29/06/2005)

Chapter 6C: Models within MISHAP01 for risk assessment of pipelines conveying natural gas

Introduction

1. Use of MISHAP01 for natural gas pipelines is described in PCAG Chapter 6C. The purpose of this PCAS chapter is to describe the underlying mathematical models and to give some demonstration of their validity.

2. The mathematical models used in MISHAP01 for natural gas pipelines are:-

   LOSSP to calculate the rate of release of gas from the pipeline;

   FBALL to calculate the size of, duration of, and thermal radiation from a fireball;

   PIPEFIRE to calculate the size of, and thermal radiation from, a natural gas jet-fire;

chp_06p – (07/09/2005)

Chapter 6P: Risk assessment for pipelines conveying flammable substances other than natural gas

INTRODUCTION

1. The risk assessment methods described in this Chapter and in Chapters 6C and 6Q enable MSDU to provide consistent advice on land-use planning zones in the vicinity of major accident hazard pipelines, defined in Part III of The Pipelines Safety Regulations (PSR) 1996.

This has allowed replica models to be developed for UKOPA:-

Results Comparison - Full Listing of HSE Gas Pipelines

Select Row No	**33**			
Diameter	914.4			
MAOP	70			
Wall thickness	12.7			
Steel	X60			
Depth of Cover	900	**RESULTS**		
Design factor	0.610169			
Area Class'n	R-pipe	HSE	1 cpm	264
BPD (from TD1)	77.999	Calculated	1 cpm	261
Rupture Rate	0.0108			
Large Hole	0.0012	HSE	0.3 cpm	279
Small Hole	0.0104	Calculated	0.3 cpm	282
Pin Hole	0.14			
Total Failure Rate	**0.162**			

Fireball outside 1000tdu	392
Jetfire escape distance 1000tdu	287
Fireball pilot ignition distance	275

Risk Calculation Input + Results

Pressure	70	bar
Diameter	914.4	mm
Rupture	0.0108	
110 mm hole	0.0012	
75 mm hole	0.0104	

Calculate risk

Distance to		
Inner Zone	0	metres
Middle Zone	261	metres
Outer Zone	282	metres

Initial Methane Gas Release Rate
2 open ends rupture of pipeline

Input data

Initial Gas Pressure	70	Barg
Initial Gas Temperature	10	Deg C
Internal Diameter of pipeline	914.4	mm

Results

Gas Density	59.5	Kg/M3
Release rate	12378.59	Kg/M2.sec
Area of open ends	1.31339	M2
Initial release rate	**16258**	kg/sec
Length of Pipeline released	16000	metres

Falling Release Rate from Pipeline

Instantaneous release rate C1	16257.86
Steady state release rate C2	4487
Mass in system Kg M	625269.4
C3 = C1 + C2	20744.86
B1 = (W x C2) / (C1^2)	10.61442
B2 = W / C2	139.3513
30 second flowrate (used for jetfire and flash fire)	**3930.6**
15 minutes flowrate	1761.0

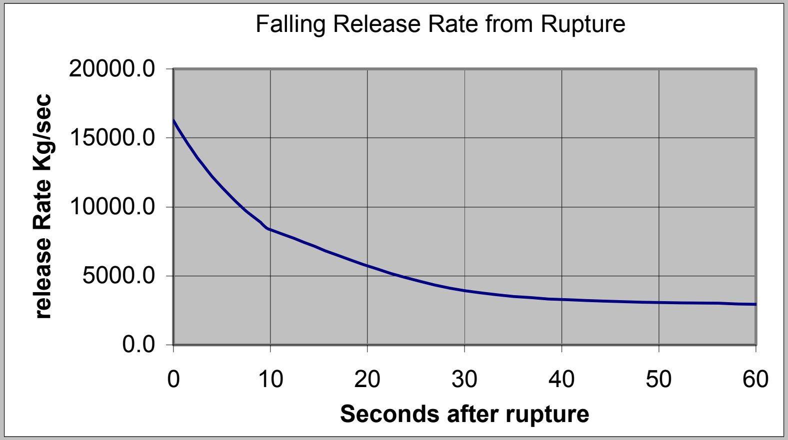
Time seconds	Release rate kg/sec
0	16257.9
1	15099.7
2	14044.7
3	13083.4
4	12207.6
5	11409.5
6	10682.1
7	10019.2
8	9414.8
9	8863.8
10	8361.4
30	3930.6
60	2946.0
90	2682.6
180	2241.4
300	1962.5
900	1761.0

Methane Gas Steady State Release Rate
Calculate Flowrate for Pressure Drop down pipeline length

Input data

Pipeline diameter	914.4	mm
Initial Gas Pressure	70	barg
Initial Gas Temperature	10	Deg C
Length of Pipeline	8000	metres
Steady State release rate	**4487**	kg/sec
Calculated pipeline length	**7998**	metres

Calculate Length



Methane Gas Fireball Calculations

INPUT DATA	Rupture	110 mm	75 mm
Instantaneous release rate C1	16257.86	78.32	36.41
Steady state release rate C2	4487	70.4916	32.7699
Mass in system M	625269.4	625269.4	625269.4
Atmospheric humidity %	60	60	60
RESULTS			
Quantity in Fireball - kg	188133.3	224.6	71.2
Duration of Fireball - seconds	20.58	2.87	1.95
Fireball radius - metres	168	19	13
Required kW/m2 for Spont Combustion	40.51	97.76	123.63
Distance to Spont Combustion metres	**212**	18.93	13.06
Required kW/m2 for Pilot Ignition	30.47	73.36	90.43
Distance to Pilot Ignition metres	**275**	21.73	13.06
Required thermal radiation for 1800 tdu	28.60	125.41	167.15
Distance to 1800 tdu LD50 metres	**292**	19	13.06
Required thermal radiation for 1000 tdu	18.41	80.70	107.56
Distance to 1000 tdu LD01 metres	**392**	19	13.06
Default distance to 25.6 kW/m2	316	**50**	**35**

Fireball Calculator

HSE Jet Fire Calculation View Factor Method

Calculate

	Rupture	110 mm hole	75 mm hole
Release rate at 30 seconds kg/sec	3931	78	36
Flame diameter and length from HSE			
Flame Width - HSE Equation	109.2	15.7	9.4
Flame Height - HSE Equation	701.7	89.0	55.0
Lift off height	0.0	12.1	10.2
Relative humidity - uses standard HSE equation	50	50	50
Continuous spontaneous ignition flux kW/m2	25.6	25.6	25.7
Distance to Continuous Spontaneous Ignition	**181**	**35**	**22**
View Factor	0.143197		
Continuous pilot ignition flux kW/m2	14.7	14.7	14.7
Distance to Continuous Pilot Ignition	**304**	**56**	**35**
Dose to person running at 2.5 m/sec for 30 sec	1799.7	13.9	13.9
Distance from which person running will escape	**181**	**59**	**37**
Dose to person running at 2.5 m/sec for 30 sec	999.2	996.9	998.6
Distance from which person running will escape	**287**	**31**	**13**

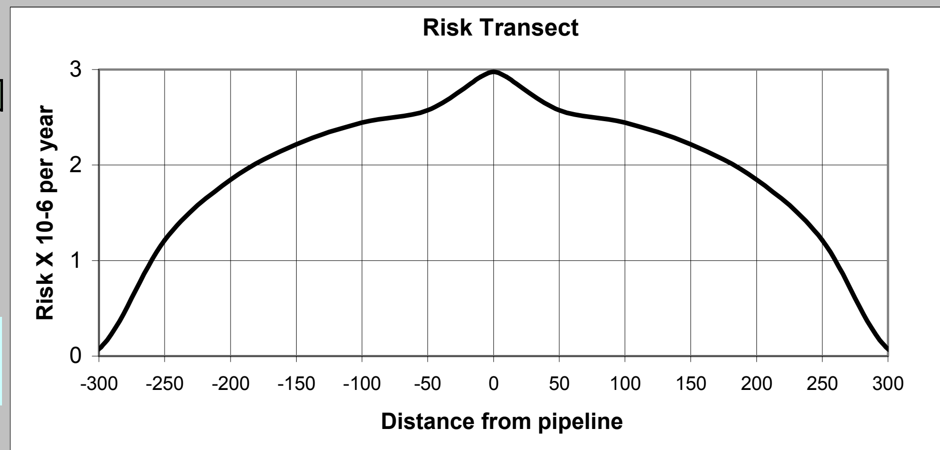
Risk Transect Calculation

Failure rate data - per 1000 kilometre-years	75 mm	110 mm	Rupture	Total	Consequence Analysis - distance to effect		75 mm	110 mm	Rupture	Probabilities from Event Tree
					Fireball out	1000 tdu	35	50	392	0.25
External Interference					Fireball inside	Pilot Ign			275	
Mechanical Defect										0.4375
Corrosion					Jet fire	1000 tdu	13	31	287	0.1875
Ground Movement					Proportion out	daytime	0.1			
Total	0.0104	0.0012	0.0108	0.0224	Proportion out	nightime	0.01			
									no ignition	0.3125

Diameter of pipeline mm	914.4

Calc Risk levels

Distance to 10-5	**0**
Distance to 10-6	**261**
Distance to 3 x 10-7	**282**



Total Risk	**0.30**	**0.00**	**0.05**	**0.07**	**1.21**	**1.85**	**2.22**	**2.44**	**2.57**	**2.92**	**2.98**
Distance from pipeline	282	-400	-350	-300	-250	-200	-150	-100	-50	-10	0
75 mm fireball outside	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1731	0.1807
75 mm jetfire 1000 tdu	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0770	0.1192
110 mm fireball outside	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0291	0.0297
110 mm jetfire 1000 tdu	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0309	0.0327
Rupture fireball outside day	0.0735	0.0000	0.0476	0.0681	0.0815	0.0910	0.0978	0.1023	0.1049	0.1058	0.1058
Rupture fireball outside night	0.0073	0.0000	0.0048	0.0068	0.0081	0.0091	0.0098	0.0102	0.0105	0.0106	0.0106
Rupture fireball inside	0.0000	0.0000	0.0000	0.0000	0.5519	0.9143	1.1178	1.2428	1.3122	1.3336	1.3345
Rupture jetfire 1000 tdu	0.2160	0.0000	0.0000	0.0000	0.5709	0.8336	0.9910	1.0895	1.1446	1.1616	1.1624

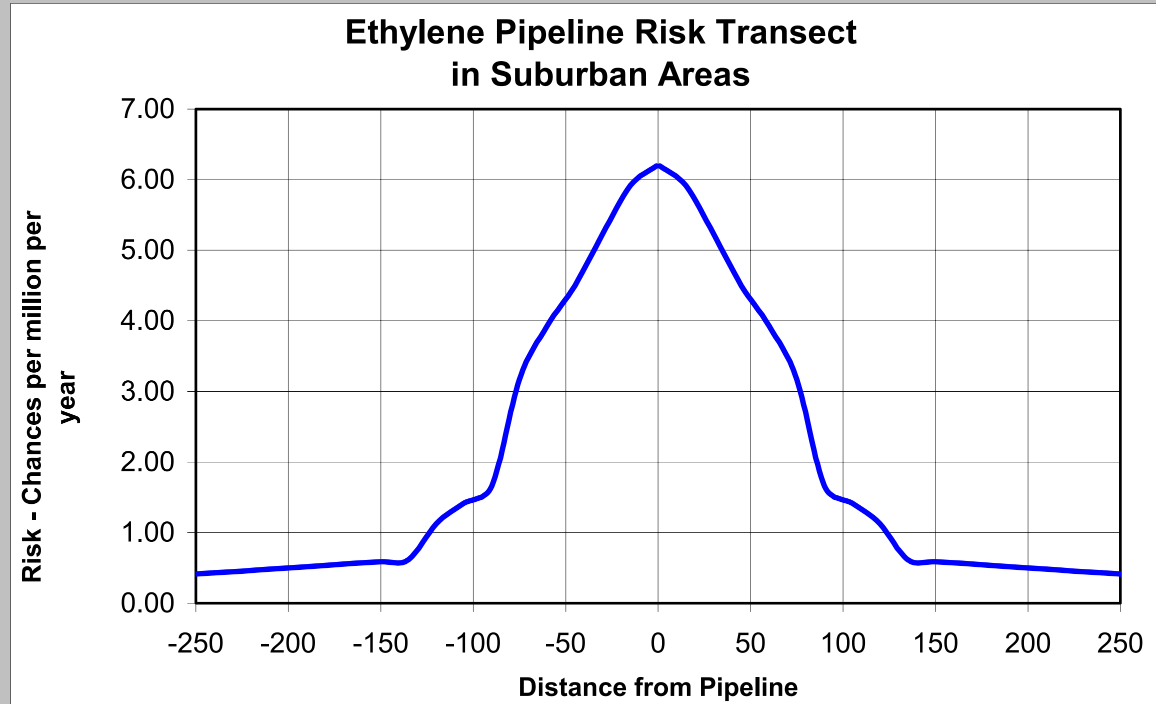
Similarly for ethylene:-

Ethylene Pipeline Risk Transect

Maximum Distance	**360**
Increments to calculate	**15**

Calculate

Inner Zone 10-5	**0**
Middle Zone to 10-6	**126**
Outer Zone to 3 x 10-7	**323**



					Risk	**6.20**	**5.92**	**5.23**	**4.50**	**3.93**	**3.17**	**1.66**
Scenario and Wind Direction	Frequency per metre x 10-6	Circular Radius	Ellipse Length	Ellipse Width	**Distance**	**1**	**15**	**30**	**45**	**60**	**75**	**90**
Rupture Flash Fire Daytime	0.0035503	0.44144	415	183	Ellipse	0.51	0.51	0.49	0.47	0.45	0.43	0.41
Rupture Flash Fire Nightime	0.0008876	0.47431	881	418	Ellipse	0.29	0.29	0.28	0.28	0.28	0.27	0.27
110 mm hole Flash Fire Daytime	0.0003663	0.43271	220	95	Ellipse	0.03	0.03	0.02	0.02	0.02	0.02	0.02
110 mm hole Flash Fire Nightime	9.158E-05	0.46854	497	233	Ellipse	0.02	0.02	0.02	0.02	0.02	0.01	0.01
40 mm hole Flash Fire Daytime	0.0028254	0.25633	16	4	Ellipse	0.01	0.00					
40 mm hole Flash Fire Nightime	0.0007063	0.43595	85	37	Ellipse	0.021	0.017	0.013	0.009	0.006	0.002	
Rupture fireball outside	0.0006241	110.0			Circle	0.137	0.136	0.132	0.125	0.115	0.100	0.079
Rupture fireball inside	0.0062408	84.7			Circle	1.057	1.040	0.988	0.895	0.746	0.491	

Developments in Land Use Planning Risk Assessments

Natural gas pipelines:-

- MISHAP initial release rate – appears high
- Failure rates – appear high for small diameter pipelines
- Ground movement failure rate – work with British Geological Survey allows lower "background" failure rate for most of network

Non-natural gas pipelines:-

- PIPETECH computer program shows lower initial release rates for spiked crude and ethylene
- Pessimistic ignition probabilities:-

	Natural Gas	Non-Natural Gas
Fireball	25%	20%
Jetfire	18.75%	51.20%
Daytime Flash Fire	0%	10.24%
Nightime Flash Fire	0%	2.56%
No Ignition	56.25%	16%

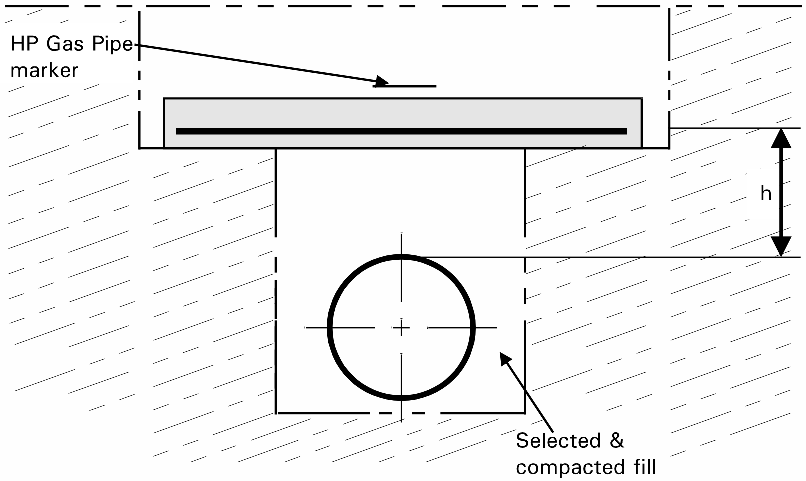
Non-natural gas pipelines:-

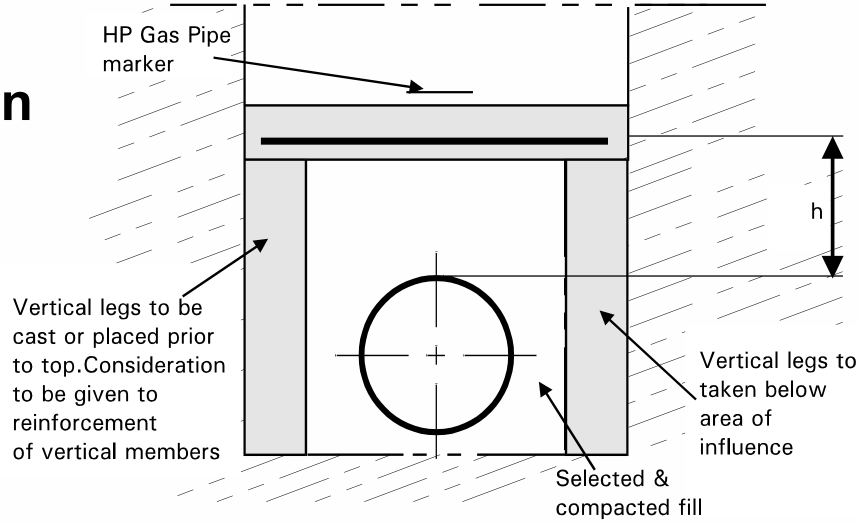
- Use of UKOPA data (i.e. UK experience) for failure rates
- Flash fire – gas dispersion distances use old (pessimistic?) models
- Flash fire – ignition assumed to take place at end of dispersed plume
- Spiked crude – issues over size of jet fire
- LPG / propane – use of PIPETECH?
- Gasoline pipelines – new LUP risk calculation (more later)

Concrete Slabbing over Pipeline – Reduces 3rd Party Interference

Extensive trials by British Gas in early 1990s showed :-

- **substantial reduction in risk by protecting pipeline with slabbing and marker tape (no damage in 30 trials)**
- **combination of mechanical protection (slabbing) and human factors (tape)**
- **risk reduction factor developed by Fault Tree analysis**
- **allow risk reduction for site-specific cases**





Code Supplements for IGE/TD/1 and PD 8010 Part 3 Risk Reduction due to concrete slabbing

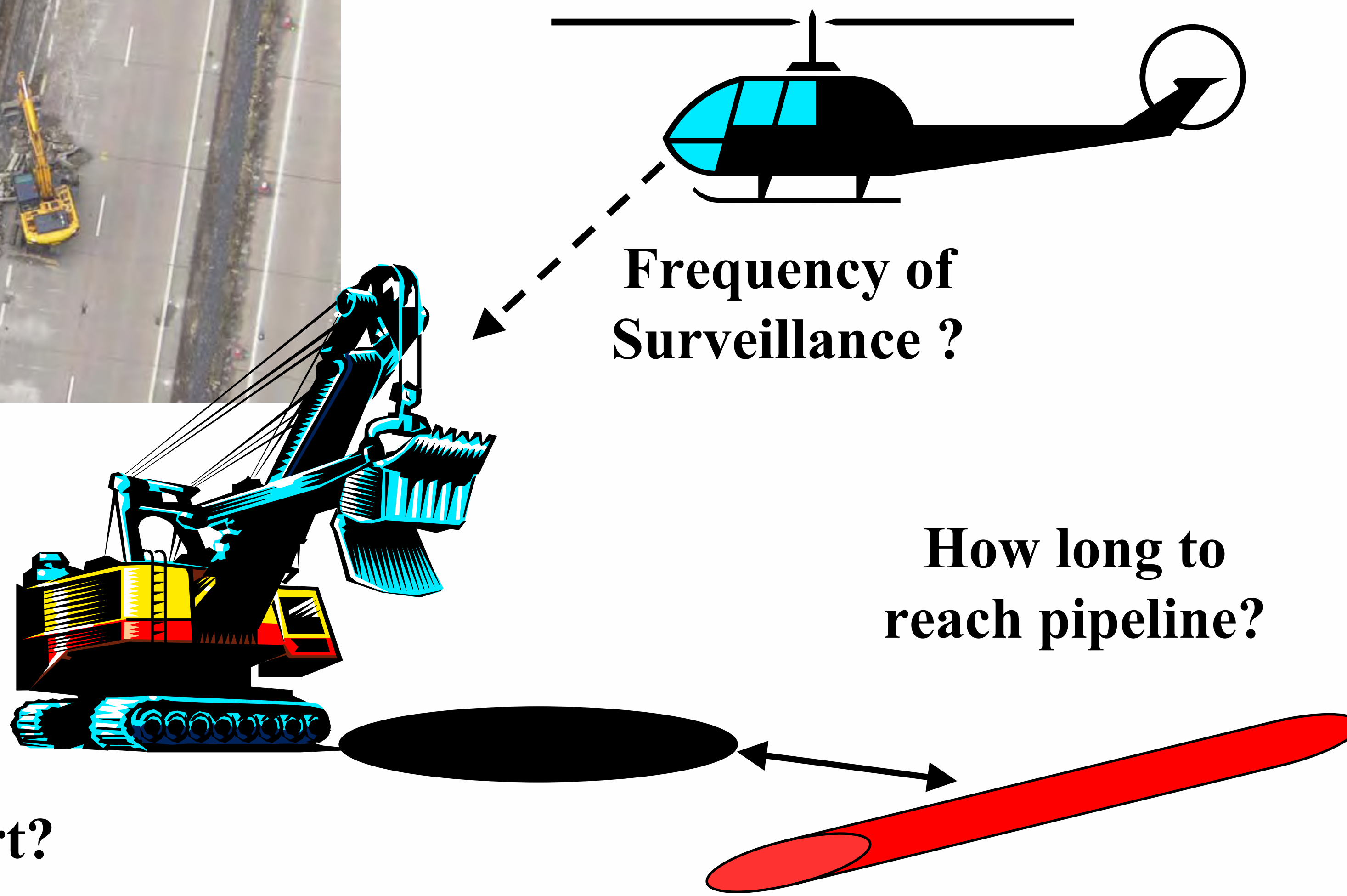
Table 1 – Failure frequency reduction factors, R_p, for pipeline protection

Measure	Reduction factor R_p
Installation of concrete slab protection	0.16
Installation of concrete slab protection plus visible warning	0.05

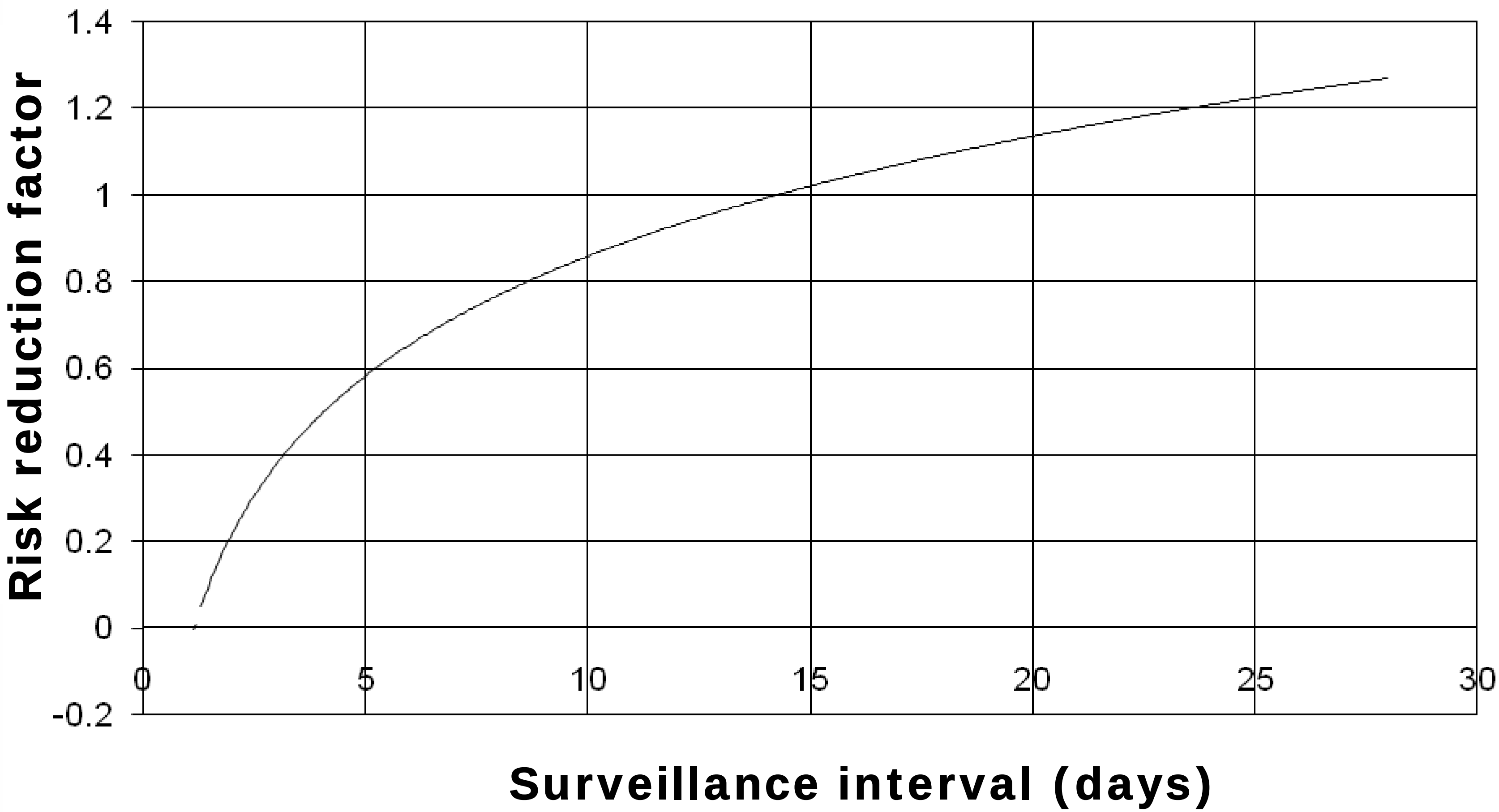
NOTE 1 Concrete slabbing with high visibility marker tapes has been shown to achieve significant risk reduction factors below 0.1 [27].

NOTE 2 In order to use the reduction factor, the physical barrier mitigation measures should apply to the whole pipeline interaction length for every failure that has to be considered.

Mitigation methods – increased surveillance

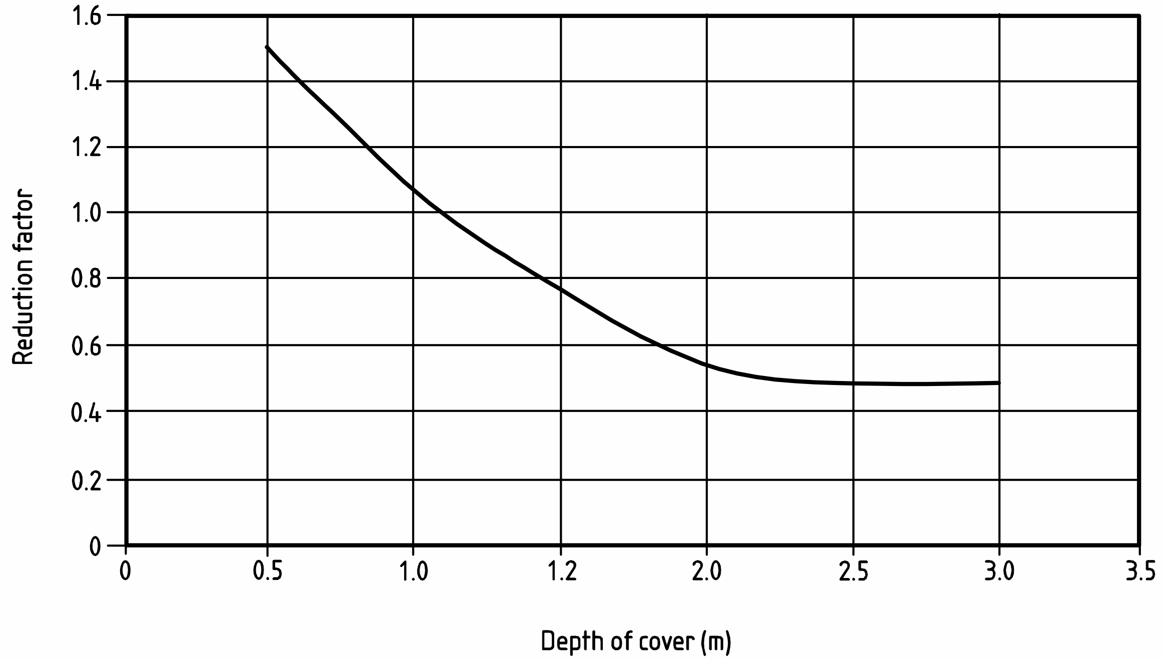


Code Supplements for IGE/TD/1 and PD 8010 Part 3 Risk Reduction due to increased surveillance



Code Supplements for IGE/TD/1 and PD 8010 Part 3
Reduction in External Interference Failure Frequency Due to Depth of Cover

Figure 1 – Reduction in external interference total failure frequency due to depth of cover



Depth - metres	Reduction - %
>2.2 m	50%
2.0 m	55%
1.5 m	65%
1.1 m	100%
1.0 m	110%
0.9 m	120%
0.8 m	130%
0.6 m	150%

Conclusions

1 UKOPA has achieved very good, open discussions with HSE leading to a more transparent process for setting Land Use Planning zone distances.

2 Need to review some anomalies in HSE's calculation methods for some LUP zone distances – e.g. ground movement, predictive modelling, over-conservative application of failure rate data from CONCAWE, etc. - HSL are working on these.

3 Use failure rate data based on UK experience for all UK pipelines, not just natural gas pipelines.

4 Allow for risk reduction measures in site specific cases – mitigation such as concrete slabbing over a pipeline, additional depth of cover, etc. - *"cost-effective risk reduction measures".*

5 Joint discussions for ongoing review and update of consequence models, release rates, jet fire, fireball, ignition probability etc. as better scientific data becomes available.

Many of these aspects are outlined in the new Code Supplements