RAWG/08/020

Briefing Note HSE Issue 09 – Methodology to Assess Gasoline Land Use Planning Zones

22 April 2008

Introduction

1 During HSE-UKOPA discussions in 2003-4 it became apparent that there were differences in approach which meant that the calculation of LUP zones for gasoline pipelines was not resolved.

2 In particular there were concerns with the HSE's proposed methodology which described a 100 metres diameter pool size based on bunds for storage tanks, and the PIPIN data for failure rates was not logical resulting in larger middle zones for smaller pipelines.

3 In July 2004, HSE decided not to proceed with revisions to PSR which would have included gasoline as a Dangerous Substance. Following the Buncefield fire it has now been decided to proceed with changes to PSR which are likely to include gasoline as a Dangerous Substance in 2009-10. Therefore there is a need to develop a methodology which calculates the Land Use Planning Zones.

4 UKOPA gasoline pipeline operators have carried out extensive risk assessment over the past 4 years, and this has resulted in a better understanding of the key factors underlying the risks from gasoline pipelines.

5 This has allowed key parameters to be identified, and enables UKOPA to propose a sensible and rational approach to assessing the risks for Land Use Planning zones.

6 The proposed methodology (attached below) was presented to HSE / HSL at Bootle on 2 November 2007. HSE raised several points, in particular concerning the calculation of the inner zone, the response time for leak identification and pump shutoff, and the use of ground soak-in.

7 Nevertheless UKOPA gasoline pipeline operators believe the proposed UKOPA methodology provides a sufficiently conservative and rational approach to allow Land Use Planning zones to be calculated and HSE are requested to adopt this approach.

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22 April 2008

Gasoline Pipelines – Possible inclusion as MAHPs in PSR 1996
Proposed Methodology to Determine Land Use Planning Zones

1 Introduction

At the UKOPA meeting on 8 February 2007, HSE confirmed that they expect gasoline to be included as a Major Accident Hazard substance under PSR 96. The earliest likely date for changes to legislation would be October 2008. On 12 February 2007, UKOPA gasoline pipeline operators met to consider the implications and methodology for calculation of Land Use Planning Zones for gasoline pipelines. This note summarises developments to the proposed methodology as discussed at the meeting.

The methodology is for assessment of generic Land Use Planning Zones for the main cross-country pipelines in the UK. Specific pipelines and locations may have different characteristics justifying site-specific features and aspects that might change the results obtained for some cases.

2 Inner Zone for Gasoline Pipelines

Existing Major Accident Hazard Pipelines (MAHPs), such as high pressure natural gas and dense-phase ethylene, do not show risk levels above 10^{-5} per year, and therefore do not have inner zones set by quantified risk assessment (QRA). In the past, HSE have set inner zones for pipelines by consequence (e.g. fireball radius) or by separation distance specified by the pipeline Code (Building Proximity Distance in IGE/TD/1)

Unlike gas pipelines, the release rate from a typical ruptured liquid pipeline is not related to pressure, but to pumped flowrate through the pipeline. Therefore the characteristic consequence-based hazard zone for a gasoline pipeline could be considered as the equilibrium pool fire radius, even though such a pool would take some minutes to form.

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

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

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

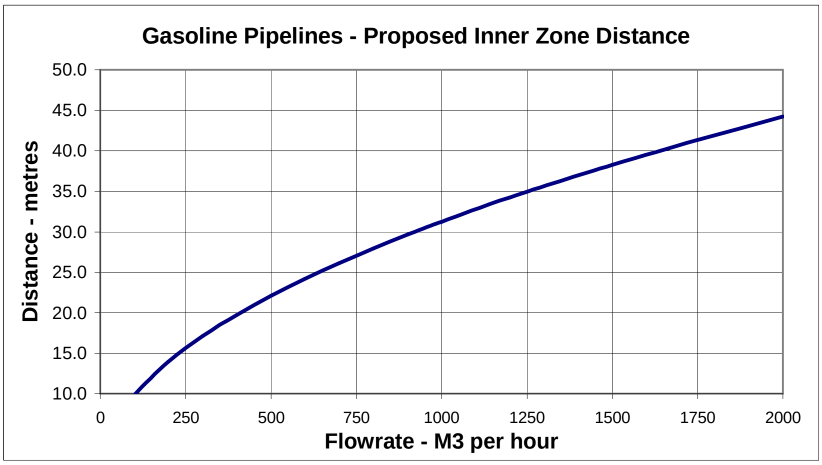
This may be simplified to:-

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

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

Figure 1 – Inner Zones for Gasoline Pipelines

Flowrate m^3/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



3 Failure Rates for Gasoline Pipelines

Failure rates for gasoline pipelines should initially be based on CONCAWE failure rates derived by UKOPA for clean product pipelines in the UK (Ref.1).

These are as shown below:-

Figure 2 – UKOPA failure rates for UK Clean Product Pipelines

CONCAWE Data derived by UKOPA for UK Product Oils

	pinhole	hole	rupture	Total
Mechanical	0.025	0.022	0.012	0.059
Natural	0.002	0.008	0.004	0.014
Corrosion	0.012	0.049	0.002	0.063
3rd Party	0.026	0.054	0.022	0.102
	0.064	0.134	0.041	0.239

CONCAWE Data derived by UKOPA for UK Product Oils

	pinhole	hole	rupture	Total
Mechanical	10.3%	9.4%	5.1%	24.8%
Natural	0.9%	3.4%	1.7%	6.0%
Corrosion	5.1%	20.5%	0.9%	26.5%
3rd Party	10.7%	22.6%	9.4%	42.7%
Total	26.9%	56.0%	17.1%	100.0%

These failure rates may then be modified for specific pipeline cases:-

a) 3rd party failure rates may be derived using predictive modelling which takes into account actual Design Factor, wall thickness, pipeline diameter, steel type etc.

b) Natural failure rates may be derived from UK-based failure rates for natural ground movement, which will be generally lower than shown above.

c) Changes to mechanical (i.e. material and construction defects), and corrosion failure rates would need to be justified and this may be more appropriate for case-specific risk assessments.

4 Release Rates from Pipeline Leaks and Ruptures

CONCAWE holes sizes are derived from amounts estimated to have been released rather than actual hole sizes. The “pinhole” release was derived from cases where less than 10m^3 was spilled, and should not be re-applied using large hole sizes such that it over-estimates quantities released when applying it to predicted failures. They are modelled here as 10 mm equivalent circular hole diameter, but do not contribute significantly towards the safety risk from gasoline pipelines.

Holes are modelled as 50mm diameter punctures. For most cases considered (except very high throughput), holes this size will release the full pumping rate through 50mm holes. Ruptures are considered to release 103% of normal pumping rate due to increase in flowrate due to lower pressure drop to the point of rupture along the pipeline. Above this rate the pumps are likely to lose suction and trip out.

5 Release Scenarios and Possible Fires

Evidence from historical incidents (Ref.2) shows that 4 scenarios should be considered:-

Sprays – approximately 16% of releases cause sprays. If these ignite, the resulting spray fires are modelled as 4 ellipses, each having an equal (25%) probability of occurring:-

- Length = 2 x pipeline pressure in bar (MAOP), with width = 80% of length
- Length = 1.5 x pipeline pressure in bar (MAOP), with width = 80% of length
- Length = pipeline pressure in bar (MAOP), with width = 80% of length
- Length = 0.5 x pipeline pressure (MAOP), with width = 80% of length

Spray fires contribute ~ 10% towards the risk from gasoline pipelines. If they do not ignite, there is still the possibility they could cause immediate or delayed ignition pool fires.

Immediate ignition pool fires – these would form the equilibrium pool fire diameter as described in section 2 above.

Delayed ignition pool fires – these would form a pool diameter over the 5 minutes taken to shut off the pumps and stop the flow in the pipeline.

No ignition – causing pollution effects to the local area.

6 Ignition Probabilities

The pipeline is assumed to be transferring gasoline when the failure occurs. Historical data indicates that the probabilities of ignition are:-

Spray fire	-	0.1
Immediate ignition pool fire	-	0.025
Delayed Ignition pool fire	-	0.025

7 Pool Fire Diameter – Ground Soak-in

Evidence from incidents (Ref.2) indicates that soil type cause a significant reduction in actual pool fire diameter. For average soils, the pool diameter is typically 70% of the maximum diameter due to gasoline soaking into the soil. Therefore equal probability (50%) of the pool being 100% diameter (i.e. wet ground or heavy clay conditions) and 70% diameter (average soil) is used in the QRA calculations.

8 Pool Fire Calculations

Standard pool fire equations are used to calculate the thermal radiation from the pool with the following assumptions:-

- Gasoline burning rate 0.067 kg/sec.m^2
- Flame surface emissive power 100 kW/m^2 (View Factor method)
- Wind velocity 5 metres /sec (11 mph)
- Wind tilt - 25% towards observer, 25% away from observer, 50% cross-wind
- Thermal radiation effect level – 14.7 kW/m^2 – for escape from pool fire for persons indoors or outdoors
- Probability of escape from fire = 0, for all scenarios – i.e. within pool fires or spray fires, and within 14.7 kW/m^2 thermal radiation areas

9 Typical Results

a) 323 mm (12”), 69 bar MAOP, 500 m3/hour throughput,
Inner Zones (based on throughput) = 22 metres
10^{-6} /year risk = 26 metres (Middle zone rounded up to 30 metres)
3 x 10^{-7} /year risk = 61 metres (Outer zone rounded up to 65 metres)

b) 406 mm (16”), 71 bar MAOP, 680 m3/hour throughput,
Inner Zones (based on throughput) = 26 metres
10^{-6} /year risk = 34 metres (Middle zone rounded up to 35 metres)
3 x 10^{-7} /year risk = 67 metres (Outer zone rounded up to 70 metres)

c) 356 mm (14”), 88.6 bar MAOP, 470 m3/hour throughput,
Inner Zones (based on throughput) = 21 metres
10^{-6} /year risk = 24 metres (Middle zone rounded up to 25 metres)
3 x 10^{-7} /year risk = 59 metres (Outer zone rounded up to 60 metres)

d) 168 mm (6”), 99.3 bar MAOP, 180 m3/hour throughput,
Inner Zones (based on throughput) = 13 metres
10^{-6} /year risk = 0 metres (Middle zone = Inner zone rounded up to 15 metres)
3 x 10^{-7} /year risk = 41 metres (Outer zone rounded up to 45 metres)

e) 273 mm (10”), 114 bar MAOP, 362 m3/hour throughput,
Inner Zones (based on throughput) = 19 metres
10^{-6} /year risk = 24 metres (Middle zone rounded up to 25 metres)
3 x 10^{-7} /year risk = 58 metres (Outer zone rounded up to 60 metres)

R A McConnell
14 February 2007

References

1. "UKOPA Review of CONCAWE data 1971-2003", Parts 1 – 4 covering product oils and crude oil, R A McConnell, April 2005

2. "Assessing the Risk from Gasoline Pipelines in the UK Based on a Review of Historical Experience", A report prepared by W S Atkins Safety & Reliability for and on behalf of The Health & Safety Executive, Report No AM5121, Issue 01, July 1998