UKOPA

United Kingdom Onshore Pipeline Operators' Association

Technical Briefing Note

The history of land use planning

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This Technical Briefing Note (TBN) identifies what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All information is guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to this TBN.

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1. EXECUTIVE SUMMARY

Land use planning (LUP) zones were imposed on Major Accident Hazard Pipelines by the Health & Safety Executive (HSE) in 1989-90. For natural gas the zones were based on multiples of the pipeline Building Proximity Distance (BPD) and for other pipelines (ethylene, LPGs, spiked crude) the zones were based on risk assessment methodologies published by HSE. These zones caused significant planning issues in areas adjacent to some pipelines due to the large size of the zones and the rigid way the planning advice was applied by HSE.

Although some operators had direct discussions with HSE, particularly Transco, the main reason for the formation of UKOPA in 1997 by pipeline operators was to provide a common industry group to lobby and discuss land use planning zones with HSE.

Major progress was made in 2002-3 with the formation of Working Group on Pipelines as part of HSE's Fundamental review of Land Use Planning. In particular a small Work Group, Risk Assessment, met numerous times during this period and as a result HSE developed and implemented risk-based land use planning zones for natural gas based on some aspects of UKOPA fault and failure data using their software called MISHAP. In addition HSE were proposing to set land use planning zones for gasoline pipelines, and UKOPA were involved in formulating how the size of these zones should be calculated. However, at the end of this process (2004) HSE withdrew from further development work and decided not to progress gasoline LUP zones.

Several significant aspects of risk assessment methodology remained unresolved so UKOPA decided to develop and publish pipeline risk assessment supplements to the pipeline codes IGEM/TD/1 and PD 8010-1 through the Institute of Gas Engineers and Managers (IGEM) and the British Standards Institution. This involved an extensive amount of work by the Risk Assessment Work Group and the documents were published in 2009 as the standard IGEM/TD/2 and the code PD 8010-3.

During this process HSE were kept involved, and briefing notes for ten specific issues were submitted and discussed with HSE including allowance for pipeline depth of cover and concrete slabbing protection. HSE initiated a programme of development work with the Health & Safety Laboratory (HSL) at Buxton, and UKOPA representatives met regularly with HSL staff to progress the ten significant issues raised with HSE.

Eventually HSE accepted most of the arguments put forward by UKOPA, and reassessment of failure rates and methodologies by the Health & Safety Laboratory specialists occurred during 2010-5 resulting in changes to HSE's methodology. In 2014-5 HSE reassessed many LUP zones based on the new data and methodologies. The most significant reduction of LUP zones was for ethylene pipelines.

Overall the close liaison between UKOPA and the HSE has proved fruitful resulting in a realistic, and generally agreed, approach to risk-based calculations to assess land use planning zones. Pipeline Operators working collaboratively with the Regulator can be considered to be a major success resulting from the formation of UKOPA.

This TBN documents the history of UKOPA's involvement in the development of LUP zones for Major Accident Hazard Pipelines between 1997 and 2015.

2. INTRODUCTION

The Pipelines Safety Regulations 1996 [1] defines a “major accident hazard pipeline” (MAHP) as one which conveys a dangerous fluid. Schedule 2 describes “dangerous fluids” which includes flammable gases above 8 bar absolute, flammable liquids with a boiling point below 5°C at 1 bar absolute, a liquid which has a vapour pressure greater than 1.5 bara at 20°C, and other defined categories including toxic or very toxic fluids. The pipelines defined as major accident hazard pipelines include natural gas, ethylene, NGLs, LPGs, and spiked crude but not currently gasoline.

Land use planning (LUP) zones were imposed on Major Accident Hazard Pipelines by the Health & Safety Executive (HSE) in 1989-90. For natural gas the zones were based on multiples of the pipeline Building Proximity Distance (BPD) and for other pipelines (ethylene, LPGs, spiked crude) the zones were based on risk assessment methodologies published by HSE. These zones caused significant planning issues in areas adjacent to some pipelines due to their large size and the rigid way the planning advice was applied by HSE.

The main reason for the formation of UKOPA in 1997 by pipeline operators was to provide a common industry group to lobby and discuss land use planning zones with HSE. The objective of this TBN is to highlight the history of UKOPA’s involvement in the development of realistic and quantifiably demonstrable Land Use Planning Zones for Major Accident Hazard Pipelines.

2.1 Abbreviations

ACDS	Advisory Committee on Dangerous Substances
ACMH	Advisory Committee on Major Hazards
ALARP	As Low as Reasonably Practicable
BPD	Building Proximity Distance
BSI	British Standards Institution
CIMAH	Control of Industrial Major Accident Hazards
cpm	chances per million
EEC	European Economic Community
FORM	First Order Reliability Method
HSE	Health and Safety Executive
HSL	Health & Safety Laboratory
IGEM	Institution of Gas Engineers & Managers
IPFRLUP	Implementation Project for the Fundamental Review of Land Use Planning
LPG	Liquid Petroleum Gas
LUP	Land Use Planning
MAHP	Major Accident Hazard Pipeline
MDOB	Maximum Distance to Occupied Buildings
MHI	Major Hazard Installation
MSDU	Methodology and Systems Development Unit

NGL	Natural Gas Liquids
PADHI	Planning Advice for Development near Hazardous Installations
PD	Published Document
PSR	Pipelines Safety Regulations
SMYS	Specified Minimum Yield Strength
SORM	Second Order Reliability Method
TBN	Technical Briefing Note
UKOPA	United Kingdom Onshore Pipeline Operators' Association
UKPIA	United Kingdom Petroleum Industry Association
WGP	Working Group on Pipelines

3. BACKGROUND TO LAND USE PLANNING NEAR PIPELINES

Land Use Planning (LUP) describes the process of applying zones to Major Hazard Installations (MHI), including pipelines, inside which there are restrictions on planning. The purpose of the zones is to limit (or reduce) the number of people who might be affected by a major accident at the MHI.

3.1 The Reasons for Land Use Planning

The Flixborough disaster, which occurred on Saturday 1st June 1974 and killed 28 site workers, also caused damage to houses up to 3 miles from the site, and resulted in the setting up of the Advisory Committee on Major Hazards (ACMH). They produced 3 reports over the subsequent years [2], [3], [4], resulting in the CIMAH (Control of Industrial Major Accident Hazards) Regulations in 1984 [5]. These regulations established a "Consultation Zone" around Major Hazard chemical sites in which new planning developments had to be sent by Local Planning Authorities to the HSE for their advice. The process was given impetus by the Seveso disaster (1976) and subsequent EEC Seveso directive (1982), the Bhopal disaster (1984) and the Mexico City disaster (1984).

Zones were applied to fixed sites during the mid-1980s. Initially the purpose of the zones was to stabilise and reduce the number of people who could be harmed by a major accident. However, pragmatism has prevailed, and stabilisation of numbers, reduction and stabilisation where possible, combined with limited increases in numbers of people in the middle and outer zones, is now accepted as a reasonable way forward for all stakeholders.

3.2 Derivation and Definition of Land Use Planning Zones

At first there was a simple Consultation Zone or CZ. This was defined as the zone within which HSE were consulted if a new planning application was made which increased the number of people living or working within the zone. Initially the zone was defined as the fireball radius for the largest accident on the site involving flammable materials like LPG, or standard distances based on toxic gas dispersion for toxic sites. Typically, zones varied from 500 metres to 3 kilometres from Major Hazard Installations (MHIs).

A notable case occurred at Pheasants Wood, Fleetwood in Lancashire (1980), when a court case allowed a planning development to proceed because HSE's case was purely based on the consequences of a release of toxic gas. This forced HSE to reconsider and apply a risk-based approach which meant that the zone calculation had to take into account the likelihood of a release affecting people as well the possible consequences in the event of a release.

Later development of the HSE criteria into three zones (inner, middle and outer) was established by the publication in 1989 of the document "Risk Criteria for Land Use Planning in the Vicinity of Major Industrial Hazards" [6] This detailed the equivalent risk levels for the 3 zone boundaries as follows:

- the inner zone, closest to the MHI – risk level greater than 10 in a million per year of a dangerous dose (approximately equivalent to 1% of the population suffering fatal injuries), also shown as 10^{-5} per year, or 10 cpm (chances per million per year);
- the middle zone – risk level between 10 in a million per year and 1 in a million per year 10^{-6} (or between 10 cpm and 1 cpm);

- the outer zone – risk level between 1 in a million per year and 0.3 in a million per year 3 x 10^{-7} (or between 1 cpm and 0.3 cpm). Outside this zone there are no restrictions.

3.3 History and Basis for Applying Zones to Pipelines

Pipelines were not covered by the CIMAH regulations and so were not initially classified as MHIs. However, in the late 1980s, papers were presented by HSE inspectors at pipeline conferences describing how they had developed a risk-based methodology to be applied to ethylene pipelines. In 1989, operators of ethylene and some other pipelines received notification that LUP zones would be applied to their pipelines.

The published papers are somewhat unclear on the authority for imposing these zones on existing pipelines, for example they stated, “subsequent proposals for development in the vicinity of such pipelines (i.e. notified under NIHHS regulations [7]) are subject to planning controls on the grounds of safety” (Carter 1989). When later challenged on their authority for applying LUP zones to pipelines (during 1998-9) HSE quoted Town and Country Planning acts, and their statutory duty for safety in the UK.

Gas transmission pipelines were covered by the Gas Act 1995 [8] and when the Pipeline Safety Regulations [1] came into force in 1996, the HSE initially imposed LUP zones based on multiples of Building Proximity Distances (BPDs). These are distances specified in the IGEM standard IGEM/TD/1 [9] for the minimum proximity of pipelines to normally occupied buildings. For a 24” diameter pipeline, with a design factor 0.72 and a maximum operating pressure of 70 bar in a rural area, the BPD is 77 metres. Therefore, HSE typically defined the LUP zones as follows:

- inner zone = 2 x BPD = 154 metres
- middle zone = 3 x BPD = 231 metres
- outer zone = 4 x BPD = 308 metres

The Pipelines Safety Regulations [1] defines Major Accident Hazard Pipelines (MAHP) and also reiterates the Department of Trade and Industry’s responsibilities, under the Pipelines Act 1962 [10], to consult HSE on the route of new cross-country pipelines. However, no mention is made of LUP zones adjacent to Major Accident Hazard Pipelines, or HSE’s role as Statutory Consultee for developments near existing pipelines.

PSR 96 Regulation 20 places duties on MAHP operators to notify HSE of the pipeline details (defined in Schedule 4 of PSR 96). This duty was applied retrospectively to all operating MAHPs. On receipt of the pipeline notification details, HSE then notified Local Authorities of the presence of the pipeline for inclusion in the Local Authority emergency plan and provided LUP consultation distances for the pipelines.

3.4 Concerns Raised by Pipeline Operators

Setting up zones next to pipelines started to cause issues in the early 1990s. Often, pipeline operators would find excavators on land adjacent to pipelines starting to build new housing estates, when carrying out routine pipeline surveillance. There appeared to be no mechanisms for informing all the Local Planning Authorities about high hazard pipelines in

their area which had newly-imposed land use planning zones. Operators were therefore not told of proposed new developments near their pipelines.

When HSE stepped in, and advised against a new development, the pipeline operator was threatened with a court case by the developer seeking compensation for loss of a lucrative development project.

4. CURRENT APPROACH FOR PIPELINE LAND USE PLANNING ZONES

In the UK, the LUP zones are classified into 3 levels as shown below:

- the inner zone, closest to the MHI – for a typical pipeline this might be 30 to 90 metres each side of the pipeline. The inner zone represents an individual risk level exceeding 10^{-5} per year, but most UK MAHPs do not reach this risk level, so HSE now use the Building Proximity Distance (BPD) as defined in IGEM/TD/1 [9] for gas pipelines and the Minimum Distance to Occupied Buildings (MDOB) for other fluids as defined by PD 8010-1 [11]

- the middle zone – typically 80 to 250 metres, representing individual risk level exceeding 10^{-6} per year but less than 10^{-5} per year

- the outer zone – typically 100 to 250 metres (but could be up to 450 metres), representing individual risk level exceeding 3 x 10^{-7} per year but less than 10^{-6} per year

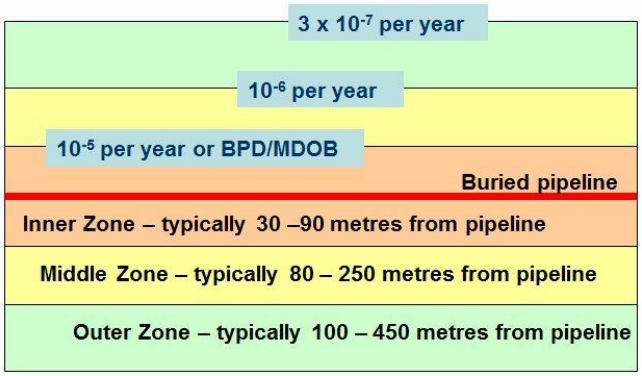

Figure 4.1: Land Use Planning Zones Next to Pipelines

Inside the zones, planning applications for new housing, shops, or other developments, are assessed using detailed guidance produced and published by HSE [12] which describes their methodology for assessing and providing guidance on maximum population types within each zone. Local planning authorities have been supplied with a software tool which maps pipeline routes and their associated LUP zones so that they can assess planning advice without reference to HSE for most cases.

However, for cases which exceed the guidance levels, the planning applications are sent to the HSE for comment, as statutory consultee, by the local planning authority. This allows HSE to re-assess the proposed development against their current risk assessment methodology, taking into account any specific mitigation methods such as thicker wall pipe or concrete slabbing over the pipeline.

If the HSE consider that the risks are too high, they advise against the development, and in most cases, the local planning authority will subsequently refuse permission for the development to continue in its current form. If the local planning authority go against HSE advice and allow the planning application, HSE still have the right to “call in the papers” and initiate a public inquiry with an independent planning inspector appointed by government.

5. FORMATION OF UKOPA AND INITIAL REPRESENTATIONS TO HSE

5.1 Formation of the United Kingdom Onshore Pipeline Operators' Association in 1997

The first recorded meeting of pipeline operators to discuss land use planning development issues was held on 6th August 1993 at Ambergate when ICI and British Gas shared their experiences of these difficulties with planning applications.

A more formal gathering was held on 22nd February 1996 chaired by BG Transco, and attended by representatives from Shell, BPA, ICI, BP and BG, with apologies from Esso and Kinetica. Land use planning issues of common concern were shared.

A second meeting was held on 17th July 1996 when Transco shared some of the joint work being carried out on risk criteria with HSE. On 29th November 1996, a further informal meeting was held at Ambergate chaired by Transco, at which the formation of UKOPA was proposed, and the first meeting of the Association was held by ICI on Teesside on 27th February 1997. Since then Land Use Planning issues have been one of the main agenda items, progressed on several fronts, including through the Risk Assessment Work Group formed in 1998 and the Fault Data Management Group formed in 1999[1].

5.2 Issues with HSE Approach

Initially the main issues with the LUP zones imposed by HSE were twofold:

1. The large size of the LUP zones and the basis and methodology for deriving the zones; and,

2. Communication between HSE and local planning authorities so that early consultation of potential developments would prevent late intervention by HSE in cases which contravened their advice.

HSE's declared approach in their guide to the Pipelines Safety Regulations [13] (Introduction, Paragraph 2) says:

"The Pipelines Safety Regulations 1996 replace earlier prescriptive legislation on the management of pipeline safety with a more integrated, goal-setting, risk-based approach encompassing both on-shore and off-shore pipelines"

However, LUP zones (especially the British Gas multiples of BPD) were set on a consequence basis rather than a risk basis. For instance, for non-natural gas pipelines the inner zone was set on the fireball radius from a pipeline rupture (i.e. the consequences), not the 10^{-5} risk level or higher that was defined by HSE as being inner zone. Risks to people on or near a pipeline in the UK do not reach 10^{-5} so in theory, there should be no inner zone at all for pipelines. In many cases the risk on the pipeline is close to the "acceptable" or "negligible" level of risk of 10^{-6} per year, so should have relatively small "middle" and "outer" zones only.

[1] The Risk Assessment and Fault Data Working Groups were combined in 2015 to form the Fault and Risk Working Group (FARWG).

However, these low levels of risk were in conflict with the policy of setting an inner zone for pipelines, and the application of a risk-based policy of HSE's Land Use Planning zones. This conflict was apparently resolved with a letter from David Eves, Deputy Director General of the HSE to Mr P Smith, Area Director of BG Transco dated 24th August 1995 which stated:

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

Resulting from this, a joint Programme of Work was set up in 1995 by BG Transco and HSE to define the risk-based approach to Land Use Planning Zones for Transco's 19,500 km high pressure transmission system.

5.3 Transco Joint Programme of Work

Following the David Eves letter, a joint project was established. Part of this project included development of the risk criteria for inner, middle and outer zones, as well as aspects of societal risk. Extensive work was done by the joint group, especially Mike Bilo of HSE and Harry Hopkins and Ian Corder of British Gas. Much of the methodology was published, so the methods and assumptions are captured in public-domain documents.

By the end of 1996, it was reported that the development of the methodology to enable individual risk transects to be produced had been completed, and that further work on the risk matrix defining whether certain developments could proceed in the various Land Use Planning zones was nearly complete. Work on societal risk was continuing.

In terms of risk methodology development, the most significant factors included an allowance for sheltering indoors for people caught in high thermal radiation areas, a methodology for fireball calculation, escape from jet fires, and use of improved methods of failure frequency calculation.

The outcomes of the joint program were contained in a Letter of Agreement in August 1998. This showed agreement in several areas of risk assessment approach.

But three things affected the outcome in terms of new LUP zones:

1 The HSE personnel moved on to different jobs, and the new people took little or no responsibility for what had happened previously.

2 HSE decided on a new study called the "Fundamental Review of Land Use Planning", so all the risk matrix issues were revisited.

3 HSE advised BG Transco to publish their failure rate data and did agree to use Transco predictive damage distribution models to determine their LUP zones. However, the predictive model adopted by HSE was, in fact, a different version called PIPIN, produced by WS Atkins based on limited data and on work done comparing some results from the Transco model.

The request to publish BG Transco data resulted in the formation of the UKOPA Fault Database Management Group. The data was extended from just BG Transco data to include the majority of UK MAHPs; it includes not only failures but also field-verified faults. This data was subsequently published by UKOPA through the UKOPA Fault Database. HSE were joint

members in the Fault Database Management Group and contributed to the costs of setting up the UKOPA Fault Database.

There still remained many unresolved issues of approach and methodology which concerned UKOPA members, especially the risk reduction aspects of pipeline engineering which meant that many pipelines had excessive LUP zones and risk reduction could not be justified by established risk assessment methods.

6. JOINT PROGRAMME OF WORK WITH UKOPA 2001-2004

6.1 Setting up the Working Group on Pipelines (WGP)

UKOPA made high-level representations to HSE, and in February 2001, a meeting was held with Kevin Allars (Acting Head of Hazardous Installations Policy Division) and Robert Turner (Head of Methodology and Systems Development Unit (MSDU)).

HSE agreed to move the issues forward, and a new sub-committee was set up called the Working Group on Pipelines (WGP), reporting through the Major Hazards Sub-committee to the Advisory Committee on Dangerous Substances (ACDS).

The ACDS was a policy-making body and part of the Health & Safety Commission, so therefore (nominally) had more authority to decide policy than HSE. In reality this was debatable, because the actual details of risk assessments and the application of the criteria remained with the "experts" in HSE's central MSDU at Bootle. However the willingness for engagement in dialogue and the possibility of a joint approach was welcomed by UKOPA.

A joint technical workshop was held on 27th November 2001 when a range of issues were shared with HSE. A new Working Party (Risk Assessment) was set up, and in February-March 2002, new failure rates using the UKOPA Fault Database results were used, improved consequence models were applied through the HSE program MISHAP, results compared from Transco's and HSE's models, and new Land Use Planning zones calculated for all Transco's pipelines. This was seen as excellent progress by UKOPA representatives.

There were still one or two issues of difference in approach. HSE decided to apply a risk-based approach to suburban pipelines with design factor below 0.3. Previously these pipelines only had a nominal (5-15 metre) zones. Due to an anomaly in the HSE's predictive model, the failure rate for these pipelines was too high, and some of the zones were calculated to be excessively large and unrealistic.

HSE also used a single data-point for ground movement failure rates – the result again grossly over-stated the risk for low design factor pipelines and so increased their zones.

Nevertheless, the general approach was good with open working with members of MSDU, supported by Robert Turner, and all reporting back to the Working Group on Pipelines chaired by Independent ACDS member, Professor Gordon Walker of Staffordshire University.

6.2 HSE Withdrawal from the WGP

In December 2002, Robert Turner was appointed to the Cabinet Office, and Martin Goose was appointed temporary head of MSDU. He attended the WGP meeting in February 2003, and announced that due to resource limitations, MSDU were withdrawing from any further involvement with WGP or to work on the issues raised by UKOPA.

He suggested instead that future involvement should be through the ongoing Implementation Project for the Fundamental Review of Land Use Planning (IPFRLUP) which had been progressing over the previous 2-3 years in HSE.

The WGP continued to meet through 2003 and 2004 without HSE involvement. However HSE risk assessment inspectors from MSDU continued to attend Working Party (Risk

Assessment) meetings throughout the period 2003-2005 to update progress on their development of LUP zones for gas pipelines. No further progress was made with UKOPA's outstanding risk issues, with no progress on the planned application of updated methodology to other substances such as ethylene or spiked crude.

6.3 HSE's Fundamental Review of Land Use Planning

The Fundamental Review was a project set up in HSE. It examined all aspects of the criteria and advice given to Local Planning Authorities.

The main objective was to codify the advice so that HSE involvement was reduced. Many issues were borderline based on previous HSE published criteria, and HSE had become an unofficial consultant for issues which were registered as "consult" in the risk matrix used by the Local Planning Authorities.

The result was a comprehensive guidance document called PADHI (Planning Advice for Development near Hazardous Installations). This was a much clearer document and allowed local HSE area inspectors to decide on the majority of planning applications inside LUP zones. Ultimately, the plan was for local planning authorities to be able to interpret the guidance – to this end a PC-based decision tool called PADHI+ was developed. This was to eventually mitigate one of UKOPA's early concerns – better communication between local planning authorities and HSE concerning developments near MAHPs.

To enable the advice to be applied, new LUP zones for all the Transco pipelines were issued in 2003, and previous zones remained for other major hazard pipelines.

UKOPA had very little involvement in terms of the development of PADHI. However, the project to implement the fundamental review was split into stages. One of these was a review of the assessment methodologies for setting LUP zones. From UKOPA involvement, it became apparent that most of HSE's available pipeline risk methodologies were seriously flawed and needed development. One glaring issue was the first and second order reliability methods (FORM/SORM) used in HSE's PIPIN predictive failure rate modelling which resulted in anomalies in the LUP zones for some pipelines.

However, it was to be many years before further developments and updating of HSE methodology was to be carried out by the Health & Safety Laboratory at Buxton.

7. GASOLINE PIPELINES

7.1 Non-Inclusion in the Pipelines Safety Regulations 1996

During discussions with the pipeline industry in the period leading up to the introduction of the Pipelines Safety Regulations (PSR) 1996 [1] the Health & Safety Executive initially proposed to include gasoline among the list of substances which would require notification under the proposed new regulations.

As a result of lobbying by the industry (United Kingdom Petroleum Industry Association UKPIA) the Health and Safety Commission decided that gasoline should be removed from the consultative document until further research into the safety of gasoline pipelines had been conducted. Therefore, the HSE commissioned two comprehensive research studies into the safety of gasoline pipelines, one by Arthur D. Little, and the other by WS Atkins. These reports were subsequently published as HSE Contract Research Reports CRR206 [14] and CRR210 [15].

These reports failed to identify a coherent methodology for setting such zones, so HSE therefore decided not to include gasoline as a major hazard substance in the initial issue of PSR 1996, but to continue to review how it could be included at a later date.

7.2 Joint HSE-UKOPA Discussions 2003-4

As part of a revision to the Pipelines Safety Regulations 1996 (PSR), ACDS had directed HSE to include gasoline as a major hazard substance. This meant it had to have (according to HSE) LUP zones.

HSE started discussions with UKOPA in 2003-4 to develop a satisfactory methodology for calculating land use planning (LUP) zones, but it became apparent that there were differences in approach which were not resolved. In particular there were concerns with the HSE's proposed methodology which described a 100 metres diameter maximum pool size which was based on bunds for storage tanks and applied illogical PIPIN data for failure rates resulting in larger middle zones for smaller diameter pipelines than for larger diameters.

UKOPA held a joint technical workshop with HSE on 25th November 2003. The case for no LUP zones for gasoline was presented, and the serious flaws in HSE's approach were highlighted which placed most of the risk on pinhole leaks.

In July 2004, HSE decided not to proceed with revisions to PSR which would have included gasoline as a Dangerous Substance.

7.3 Post-Buncefield Intention to Include Gasoline in PSR Amendments 2010

The Buncefield explosion and fire in December 2005 changed the situation and HSE then decided to proceed with changes to PSR to include gasoline as a Dangerous Substance in 2009-10. Therefore, there was a need to develop a robust methodology which calculated the LUP zones.

7.4 UKOPA Develops Robust Methodology for Calculating LUP Zones

UKOPA gasoline pipeline operators carried out extensive risk assessments over the period 2004-8, and this resulted in a better understanding of the key factors underlying the risks from gasoline pipelines. This allowed key parameters to be identified, and enabled UKOPA to propose a realistic and rational approach to assessing the risks for LUP zones. The methodology is largely based on the comprehensive survey work and methodology proposed by WS Atkins in CRR 210 [15].

The proposed methodology was presented to HSE at Bootle on 2nd 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. Nevertheless, UKOPA gasoline pipeline operators believed the proposed UKOPA methodology provided a sufficiently conservative and rational approach to allow LUP zones to be calculated and HSE were requested to adopt this approach.

After several meetings between UKOPA and HSE during 2008-2010, HSE published their cost benefit analysis for including gasoline, their approach to calculating risk zones, and the proposed LUP zones for several pipelines.

7.5 HSE Decision Not to Proceed 2012

Following a change in Government in 2010, the Coalition Government made it a key priority to reduce Regulation. New guidelines were introduced and HSE along with other Government departments reviewed all proposed regulatory measures, including the amendments to PSR, to ensure that they were in line with the Coalition's objectives. As a result, HSE decided to carry out further engagement with stakeholders and not to progress the proposed amendments to PSR at that time.

In 2012, HSE finally decided not to proceed with the original proposal to include gasoline as a named dangerous fluid under PSR, as the existing regulatory regime is sufficient to cover gasoline pipelines.

7.6 Current Situation

During the period 2005-2013, UKOPA developed two risk assessment standards, IGEM/TD/2 [16] applying to natural gas pipelines and PD 8010-3 [17] applying to other hazardous fluids, to capture all the development work carried out. The first editions were issued in December 2009 and January 2009 and both standards were revised and reissued in 2013 [18], [19]. The development of these risk assessment standards is discussed in Section 8.

It should be noted that HSE assessment methodology does not include the requirement to carry out societal risk analysis for populated sections of pipeline as specified in IGEM/TD/1 for gas pipelines, as it is implicit in their land use planning guidance. However societal risk analysis provides a robust approach to obtain a decision on whether the risk to the adjacent population is “ALARP” requiring further assessment of risk reduction measures, or “broadly tolerable” therefore requiring no further consideration of risk reduction.

Recognising that gasoline pipelines (and other oil products transported at high pressure) can impose a risk in populated areas, most UKOPA liquid pipeline operators have therefore applied the societal risk methodology to their pipeline operations and in some cases have

implemented additional risk reduction measures where the risk is estimated to exceed societal risk levels in PD 8010-3.

8. DEVELOPMENT OF RISK STANDARDS 2005-2013

8.1 Decision to Proceed with Code Supplements

Following HSE's decision to withdraw from the Working Group on Pipelines and not to progress outstanding issues, a proposal was presented to the UKOPA membership by the Risk Assessment Work Group in early 2005 to develop code supplements for IGEM and BSI. It was agreed that the UKOPA Risk Assessment Work Group would proceed with developing the code supplements for IGEM and BSI. UKOPA's intention to develop these code supplements was published to the industry in a presentation at the BSI Conference and Network Event to launch PD 8010-1:2004 on 5th May 2005. This was followed by an article in the IGEM magazine in June 2005.

The plan was to develop and publish outline methodology for each stage of the calculation of risk levels from pipelines, such that different agencies (operators, consultants, regulators etc.) would see and apply a common approach so obtaining similar results. This would improve the transparency of the calculation methodology so removing discrepancies resulting from different approaches. UKOPA maintained HSE involvement as a high priority, such that any discrepancies in approach could be discussed and, if necessary, any difference in approach could be highlighted in the codes.

8.2 Progress on Producing the Code Supplements

Work soon started on initial drafts for these codes but it soon became apparent that extensive development work was required to define and justify the various data and risk reduction factors which were to be included. Specific items included:

- Guidance on how quantified risk assessments should be carried out for developments near MAHPs;
- What information, if any, should be included on actual LUP zones;
- Details of how to calculate individual and societal risk. For the PD 8010-3 code this included publishing a societal risk FN criterion line defining the ALARP and "tolerable / broadly acceptable" regions of the FN chart based on previous HSE publications;
- How to calculate failure rates based on a graphical approach taking into account design factor and wall thickness;
- Typical calculations and results tables showing critical crack length and pipeline rupture proportions;
- Defining and justifying external interference risk reduction factors for mitigation methods including protective measures such as concrete slabbing, depth of cover over a pipeline, effect of surveillance frequency, marker posts etc.;
- Including UKOPA data for corrosion and mechanical defect failure rates and how to assess them based on pipeline age and integrity management factors;

- For the later revision of the codes, including a comprehensive methodology for assessing ground movement failure rates based on pipeline parameters and ground type;

- Including a suitable example showing how a typical land use planning development should be assessed based on HSE guidance; and,

- In both codes, it was decided that there should be an appendix describing HSE approach to land use planning assessments.

8.3 Timescale and Milestones

Initial drafts were produced throughout 2005 and 2006 and by early 2007 drafts were issued to HSE, IGEM and BSI for comment. Dr Nigel Riley and others in HSE made extensive comments on the initial drafts and became more closely involved in the development as they saw the development of the codes as a positive process.

Both IGEM and BSI elected to publish the documents as standards, IGEM published the document for gas pipelines as IGEM/TD/2, and BSI published the document for all other hazardous fluids as Part 3 of the Published Document for Pipelines, PD 8010-3. In March 2008, after several more meetings and extensive further development, the fully formatted IGEM version and in August the BSI formatted version were issued for comment. Final comments from HSE (Dr Peter Harper) and other stakeholders were considered and included where relevant, and the IGEM and BSI documents were finalised ready for issue by December 2008. The IGEM standard was issued as IGEM/TD/2 Communication 1737 in January 2009 [16], and the BSI code was issued as PD 8010-3:2009 in December 2008 [17].

The standards were seen as a major success in achieving transparency for key aspects of the methodology and gaining acceptance by HSE. Subsequent launch events and presentations were made during 2009 including an IGEM seminar in March 2009.

8.4 2013 Update

A further issue of the standards in 2013 [18], [19] contained several minor corrections to the 2009 issue including updates for HSE risk reduction factors for concrete slabbing, an improved version of the risk reduction factor graph for increased depth of cover, and inclusion of the ground movement failure rate assessment methodology. In addition the IGEM standard title was changed to “Assessing the risks from high pressure Natural Gas pipelines” to cover all aspects of risk assessment rather than being limited to proposed development.

However, the standards do not refer to HSE’s acceptance of risk reduction for depth of cover and the ethylene land use planning zones in PD 8010-3 Table A1 are now out of date following HSE’s re-assessment of these zones.

9. PROGRESSING TEN ISSUES RAISED WITH HSE 2007-2015

Following the demise of the Working Group on Pipelines in 2006, a joint working party was established to resolve outstanding technical issues between UKOPA and HSE following a joint workshop in October 2005. Terms of reference were set out in early 2006, and a list of outstanding items was crystallised into ten items to be progressed with HSE after a joint meeting in March 2007. These were produced and issued as briefing notes to HSE in early 2008 and are discussed below.

9.1 Pipeline Protection Measures

UKOPA's declared objective was persuade HSE "to accept that protective concrete slabbing over a pipeline is an acceptable risk mitigation measure and to agree the UKOPA proposed risk reduction factors". Work was carried out by Advantica in 2007-2009 applying a fault tree technique subsequently an extensive final report was issued by GL Noble Denton (previously Advantica) in 2010 [20].

After ongoing discussions HSE wrote to UKOPA in September 2011 agreeing that for LUP "second bite" cases, HSE would apply risk reduction factors of 0.15 for concrete slabbing and 0.125 for slabbing plus marker tape. Though not meeting UKOPA's view of the extent of the reduction factors, these factors were subsequently published in the HSE section of the revised risk code supplements in 2012. Finally UKOPA issued a detailed specification for protective concrete slabbing in 2013 [21], which was later issued as a Good Practice Guide [22].

9.2 Ground Movement Failure Rate

During the development of HSE's failure rates to assess Land Use Planning Zones for natural gas pipelines during 2001-2, they assigned a fixed failure rate to natural ground movement based on a single case which occurred in 1984. This fixed failure rate dominated thick wall pipe cases and generated significant LUP zones for suburban pipelines.

Unlike other failure rates where mitigation can be applied to reduce the failure rate, this fixed rate means there is no engineering mitigation available to reduce the risk because the LUP zone remains fixed whatever mitigation (very thick wall, concrete slabbing, etc.) is applied.

This issue has not been resolved and is discussed further below.

9.3 Use of UKOPA-based Failure Rate Data for Ethylene Pipelines

A planning development proposal in 2006 caused HSE to re-calculate LUP zones for a thick wall ethylene pipeline. HSE MSDU applied corrosion and mechanical failure rates based on CONCAWE data for oil pipelines [23] and as a result obtained large zones for the thick wall case, including an inner zone of 17 m, and middle and outer zones almost as large as previously notified for the standard wall case.

The CONCAWE failure rates were 1000s of times larger than equivalent UKOPA failure rates. CONCAWE pipeline failure data only includes the results of liquid pipeline failures in the UK and continental Europe and does not include ethylene or other petrochemical pipelines. Liquid pipelines are generally not MAHPs in the UK and therefore are not included

in the UKOPA database. However, the failure data for ethylene and other petrochemical pipelines is included within the UKOPA failure rates for all UK MAHPs.

After representations by UKOPA, HSE agreed to apply UKOPA failure rates, and also to apply results from an improved rupture outflow model called PipeTech [24] which considerably reduced the outflow rate from a ruptured pipeline, so reducing the fireball radius which set the inner zone distance.

9.4 Reduction in Corrosion Failure Rates for Non-Natural Gas Thicker Wall Pipelines

Planning developments near thick-wall sections of ethylene and spiked crude pipelines were resulting in “advise against” decisions from HSE during the period 2005-2006 despite the “second bite” HSE calculations using reduced failure rates for third party failure rates. At that time HSE were allowing a reduction in corrosion failure rate for thicker wall natural gas pipelines. UKOPA made the case that non-natural gas pipelines should also have a similar reduction applied.

Subsequently this approach was adopted by HSE in line with the newly published IGEM and BSI risk standards for mechanical and corrosion failure rates.

9.5 HSE 3rd Party Predictive Modelling for Smaller Diameter Pipelines

When HSE were developing their 3rd party predictive model called PIPIN in 2001-2002, it was recognised that significant differences were obtained for results from HSE’s model compared to Transco’s predictive model called FFREQ. An analysis of all HSE’s rupture failure rates indicated that they were considerably higher, especially for smaller diameter pipelines. Several anomalies in HSE’s calculated results were also identified.

HSE subsequently recognised that the main issue with the current version of PIPIN was the solution method used, called FORM/SORM. FORM is the first order reliability method and SORM is the second order reliability method. Within PIPIN the probability of failure of a pipeline was calculated using the FORM method. For a significant proportion of pipelines this solution technique failed to converge.

In 2011-12, HSL revised the calculation method and PIPIN has been successfully rewritten using a Monte Carlo solution method as opposed to FORM/SORM [25], [26], [27], [28], [29], [30], [31]. The new model reproduced results obtained from PIPIN to a good degree of comparability. To achieve a reasonable level of convergence between 1 million and 5 million iterations were required. On average (based on a dual-core, 2.4GHz PC with 2 GB RAM) this took less than 1 minute for each scenario.

HSE are now using this improved model to calculate 3rd party failure rates.

9.6 Effect of Depth of Cover on 3rd Party Failure Rates

Increasing the depth of cover is recognised as a means of reducing the likelihood of external interference damage. This reduces the proportion of excavation activities likely to reach the depth at which they could interfere with the pipeline. However, no allowance was made by HSE for land use planning assessments for depth of burial greater than the standard 1.1 metres even though they increase failure rates for depths less than this.

An original study and programme of experimental work by the British Gas Engineering Research Station in 1989 had demonstrated that there was a significant reduction in risk of excavating a deeper buried pipeline, especially when marker tape was installed above the pipeline to warn the excavation team [32].

For the first issue of the IGEM and BSI risk standards, an assessment of previously published and HSE work was synthesised to produce a graph of risk reduction factor for increased depth of cover. However, for the revised versions in 2012 UKOPA commissioned GL Noble Denton to study the issue in detail [33] and their 2012 draft report and results were used to publish the revised graph.

In 2013, HSE wrote to UKOPA stating “In conclusion, HSE will change its current policy and accept that increased depth of cover can be used to reduce pipeline failure rates (and therefore risks) due to third party activity in its land use planning risk assessments provided that pipeline operators fulfil the commitments placed on them in TD/2 and PD8010: Part 3”.

9.7 Event Trees for Non-Natural Gas Pipelines

HSE were applying an ignition probability of 0.84 (84%) for non-natural gas substances (including ethylene, spiked crude, NGLs, propane) compared to 0.4375 (43.75%) for natural gas. The background and logic for this was not recorded. The result was that Land Use Planning zones are automatically made significantly larger for non-natural gas substances.

A logical approach to reduce the ignition probabilities based on minimum ignition energy was proposed by UKOPA in 2008.

In February 2012 HSL subsequently produced a comprehensive study report [9] which recommended the same event tree for natural gas but changed the ethylene, LPG and other flammable substances event trees. Three event trees were presented covering three levels of minimum ignition energy / flammability.

The ethylene event tree used for LUP assessments was therefore changed to overall ignition probability 0.7712 (77.12%) with the fireball probability increasing from 0.2 to 0.35 (20% to 35%), and the probability of flash fire reducing from 0.128 to 0.0962 (12.8% to 9.62%). Delayed ignition jet fire probability therefore reduced from 0.512 (51.2%) to 0.325 (32.5%).

9.8 Update to CONCAWE Data for HSE’s PIPIN Assessments

Concern was raised by UKOPA about very high failure rates derived from CONCAWE data which was then being applied to HSE’s gasoline LUP assessment methodology.

In December 2012, HSL issued a comprehensive report covering failure rates for all pipeline categories including gasoline pipelines with revised CONCAWE data [34]. This was the result of extensive discussions with UKOPA and use of the UKOPA Fault Database to obtain failure rates for MAHPs. This report provides the basis for failure rates currently applied for LUP assessments.

9.9 Methodology to Assess Gasoline Land Use Planning Zones

UKOPA outlined concerns about HSE's earlier proposed methodology for gasoline pipelines LUP zones, and recommended adoption of UKOPA's approach. Section 7 above describes the background and history of gasoline pipeline LUP zones.

9.10 Natural Gas Fireball Consequence Distances

UKOPA noted that the consequence distances from the initial fireball following pipeline rupture are significantly greater using the HSE model compared to the model developed and contained within DNV GL PIPESAFE model.

The HSE method accumulates the incremental release rate from the ruptured pipeline second-by-second until the side of the fireball is equal to the burn-time assuming all gas released in contained within the fireball. This is usually 8 – 25 seconds for the population of UK gas pipelines. During this time the release rate is rapidly reducing. The method then assumes the fireball is located on the ground when calculating the thermal radiation effects.

Comparison of the PIPESAFE method have shown that the HSE method calculates a higher initial release rate (by a factor of 2-10 times), and this will therefore result in a larger fireball.

Subsequent discussions were held between DNV GL and HSL in an attempt to resolve the differences. However, HSE have decided they will continue to use their original model.

9.11 Conclusions from this Work Programme

In all these cases apart from one, ground movement/"other" failure rate (discussed below) HSE and HSL have worked with UKOPA on the issues raised and in most cases a mutually agreed approach and solution has been achieved.

10. HSE REVISED APPROACH & CHANGES TO LUP ZONES 2008-2015

HSE contracted the development work for pipeline risk assessment to the Health & Safety Laboratory at Buxton during the period 2008-2015. The programme of work commenced with the issue of UKOPA's 10 issues discussed above and has resulted in significant developments to their methodology. A series of joint meetings throughout this period was held with HSE with Dr Peter Harper usually in attendance.

Final decisions on significant changes in approach (e.g. adopting risk reduction factors for concrete slabbing and depth of cover) were taken by HSE's HID CI5 Panel (HSE's internal peer review system for land use planning issues).

Major areas affecting LUP zones include:

- Revision of HSE's predictive model for 3rd party failure rates including adopting results from the UKOPA Fault Database for hit rates;
- Adopting UKOPA failure rate data to obtain corrosion and mechanical failure rates including reducing failure rates for thicker wall pipelines;
- Agreeing to extend UKOPA failure rates to non-natural gas pipelines included in the UKOPA Fault Database;
- Agreeing to include some mitigation measures which reduce 3rd party failure rates.

The extensive programme of work is described in a series of HSE Research reports available on the HSE website:

- RR1034 - Review of the event tree structure and ignition probabilities used in HSE's pipeline risk assessment code MISHAP [25];
- RR1035 - Update of pipeline failure rates for land use planning assessments [26];
- RR1036 - Rewriting the PIPIN code to use a Monte Carlo solution approach [27];
- RR1037 - Science updates to HSE's PIPeline INtegritv model (PIPIN) [28];
- RR1038 - Data updates to HSE's PIPeline INtegritv model (PIPIN) [29];
- RR1039 - Summary of the rewrite of HSE's PIPeline INtegritv model (PIPIN) [30]; and,
- RR1040 Rewriting MISHAP: The development of MISHAP12 [31].

10.1 Revision of Ethylene LUP Zones 2014-15

The extent of LUP zones for ethylene pipelines has concerned operators since the zones were imposed in 1989. The zones were significantly larger than for natural gas pipelines, and this was largely due to two factors:

1. The higher dense phase density of ethylene (200-300 kg/m^3) compared to natural gas (30-80 kg/m^3) resulting in very large fireball radius from a ruptured pipeline;

2. The very large drifting clouds of ethylene predicted by 1980s dispersion models which resulted in large outer zone distances, especially for still night time conditions.

The first issue was resolved following discussions in 2005-6 when HSE agreed to adopt the University College, London model called PipeTech for calculating the initial 2-phase release from a ruptured ethylene pipeline. This results in release rates which are 20-30% of the original LOSSP model in HSE's PRAM and so reduces the fireball radius and the inner and middle LUP zones.

The second issue was resolved in 2015 when HSL applied a new program called DRIFT to ethylene dispersion cases, along with the new event tree described in Section 9.7 above and depth of cover reduction factors. Also, HSE agreed to apply the PD 8010-1 Minimum Distance to Occupied Buildings (MDOB) as the inner zone distance which resulted in a significant reduction compared to the previous fireball radius calculation.

The result has been a significant reduction in LUP zones for all the UK ethylene pipelines.

11. REMAINING ISSUE – HSE DEFINITION OF "OTHER" FAILURES

The original approach for thick-wall pipelines is defined in the IGEM/TD/1 code which applies a reduced Building Proximity Distance of 3 m for wall thickness greater than or equal to 11.91 mm with a design factor less than or equal to 0.3. This is based on early research work carried out by British Gas which demonstrated that such pipelines were very unlikely to rupture when impacted by earth moving machinery. A similar approach is included in PD 8010-1 for other pipelines with a calculation for MDOB.

11.1 Re-Assessment of LUP Zones by HSE 2001-2

During the development of HSE's failure rates to assess Land Use Planning Zones for natural gas pipelines during 2001-2, one pipeline rupture case (13th October 1984, Bushey Heath) was caused by ground movement, resulting in a rupture failure rate of 0.002 per 1000 km years (2×10^{-6} per km year) based on data in the UKOPA database.

This failure rate had little effect on the risks from rural pipelines where the combination of lower wall thickness and higher design factor resulted in 3rd party failure rates dominating the rupture rate. However, in suburban areas where the wall thickness is greater than 11.91 mm and the design factor is below 0.3, the rupture failure rate is dominated by this ground movement value. As a result, risk-based middle and outer land use planning zones were increased substantially because of the single point rupture ground movement failure rate.

In an analysis carried out in October 2006, the listing of HSE pipeline calculation cases contained a total of 759 calculations for pipelines with diameters 1219 mm down to 168 mm. From this total, 107 cases were identified where the contribution from natural ground movement rupture frequency exceeded 50% of the total rupture frequency.

11.2 Further Development by HSL in 2009

When the Health & Safety Laboratory (HSL) carried out further re-assessment of failure rates based on UKOPA data during 2009-2010, they decided to use 20 years data covering 1987 to 2006, so the 1984 Bushey Heath event was no longer included. However, HSL decided to include one event previously recorded in the UKOPA database as not relevant and therefore classed as "other" because it was not in the main pipe section.

This event was the Palaceknowe failure, which occurred on 22nd December 1993 and was therefore included in the 20-year 1987-2006 dataset by HSL. The failure occurred following a modification of the pipeline which involved welding a thick wall (19.1 mm) section of pipe to an existing forged end seal at a road crossing. The forged end seal was modified on site, and the connection weld was carried out on site. The failure occurred in the forged end seal close to the connection weld due to a combination of high external loading due to increased overburden on the new thick wall pipe, inadequate compaction of the backfill below this pipe which reduced support, and the presence of a concrete raft above the pipeline which concentrated the overburden on the thick wall pipe. A further contributory factor was use of an unsuitable weld procedure for the field connection weld.

The failure occurred as a leak (not a rupture) in the forged end seal component, not in the thick wall pipe. The failure resulted in a circumferential slot running between the circumferential positions of 8 o'clock and 4 o'clock. The measured total area of the slot was equivalent to a circular hole of diameter 130 mm and was therefore within the HSE definition of "rupture" which is between 110 mm diameter and full bore.

This failure was identified as unknown category “Other” and calculated a fixed failure rate of 0.0025 per 1000 kmyears (2.5 x 10^{-6} per km per year).This is now applied to all pipelines, however thick the wall.

11.3 Issues Caused by the “Other” Failure Rate

Several issues have since arisen when a sensitive development is identified within the outer zone distance from a thick wall pipeline created by the residual “other” fixed failure rate. In some cases, this is due to a planning application to develop a sensitive development (e.g. care home), and in other cases the need to route a pipeline close to a sensitive development. In both cases the option to reduce the risk by increasing wall thickness still further is not possible because the failure rate remains fixed however thick the pipe.

Extensive representations were made by UKOPA during 2010-2015 with presentations and papers describing how the Palaceknowe failure is not relevant and urging HSE to adopt a more realistic approach to this issue. However this has not met with agreement so far.

HSE point out that in theory it would therefore be possible to allow sensitive developments right up to the thick wall BPD (3 m) if the pipe wall was very thick, and they could not agree with this even where the risk levels can be shown to be low.

The issue remains unresolved.

12. CONCLUSIONS

In spite of several setbacks during the early years the close liaison between UKOPA the HSE during the period since the formation of UKOPA in 1997 has proved fruitful. This has resulted in realistic, quantifiably demonstrable and a generally agreed approach to risk-based calculations to assess Land Use Planning zones. It can be seen very much as a major success of Industry and the Regulator working collaboratively together.

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