Update to HSE's Pipeline Integrity model (PIPIN): Fracture toughness of pipeline steels in hydrogen

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The Health and Safety Executive (HSE) uses a computer code PIPIN (PIPeline INtegrity) to determine the failure frequencies of major accident hazard (MAH) pipelines for land use planning (LUP) purposes. PIPIN calculates the failure rates of pipelines for various modes of failure, including that of third party activity (TPA). The model for TPA requires the fracture toughness of the pipeline steel as an input. This is known to be adversely affected by the presence of hydrogen and must therefore be modified for the PIPIN approach to be applicable to hydrogen pipelines.

A stepwise approach for accounting for the effect of hydrogen on the fracture toughness of pipeline steels for use within PIPIN has been proposed. This is based on the use of the Kiefner correlation between Charpy impact energy and fracture toughness, which is currently used in PIPIN. The estimated fracture toughness is then reduced by a specified factor to account for the effect of hydrogen. Checks against a published data set on the fracture toughness of relevant steels in 100 bar hydrogen showed that the mean predicted toughness using the developed method was 1.29 times the actual measured toughness.

The proposed approach applies to estimations of failure frequencies for LUP purposes, where the condition of the pipe is unknown. The level of conservatism is therefore considered acceptable. The approach is not applicable to fitness-for-service determination for pipes containing known or postulated damage.

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Update to HSE's Pipeline Integrity model (PIPIN): Fracture toughness of pipeline steels in hydrogen

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Abbreviations

Abbreviation	Meaning
Ac	Cross-sectional area of Charpy v-notch specimen
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
B	Thickness (of pipe or toughness specimen)
CEGB	Central Electricity Generating Board
CT	Compact Tension (in fracture toughness testing)
CVN	Charpy v-notch
DBTT	Ductile-Brittle Transition Temperature
DVGW	Deutscher Verein des Gas und Wasserfaches
DWTT	Drop-Weight Tear Testing
E	Young’s Modulus
EPRG	European Pipeline Research Group
f	Toughness retention factor in hydrogen
FAD	Failure Assessment Diagram
HAZ	Heat Affected Zone (of welds)
IGEM	Institute of Gas Engineers and Managers
J	J-integral (In fracture toughness testing)
K	Stress intensity factor
K_{IC}	Plan strain critical stress intensity factor (Fracture toughness)

Abbreviation	Meaning
K_{IH}	Plan strain critical stress intensity factor in hydrogen
Kr	Fracture ratio= (applied K/K_{IC}) in the FAD
Lr	Ratio of reference stress to yield stress (In the FAD)
LUP	Land Use Planning
MAH	Major Accident Hazard
MISHAP	Model for estimation of Individual and Societal risk from Hazards of Pipelines
MOP	Maximum Operating Pressure
Pf	Probability of failure
PIPIN	Pipeline Integrity
R	Pipe radius
SCC	Stress Corrosion Cracking
SENB	Single Edge Notch Bend (in fracture toughness testing)
SENT	Single Edge Notch Tension (in fracture toughness testing)
σ_h	Hoop stress
T	Temperature
T27J	27J energy transition temperature in Charpy v-notch test
TPA	Third Party Activity
UEL	Uniform elongation (in tensile test)
UKOPA	United Kingdom Onshore Pipeline Operator's Association
UTS	Ultimate Tensile Strength
YS	Yield Strength

Key Messages

The Health and Safety Executive (HSE) uses a computer code PIPIN (PIPeline INtegrity) to determine the failure frequencies of major accident hazard (MAH) pipelines for land use planning (LUP) purposes. PIPIN calculates the failure rates of pipelines for various modes of failure, including that of third party activity (TPA). The model for TPA requires the fracture toughness of the pipeline steel as an input. This is known to be adversely affected by the presence of hydrogen and must therefore be modified for the PIPIN approach to be applicable to hydrogen pipelines.

A stepwise approach for accounting for the effect of hydrogen on the fracture toughness of pipeline steels for use within PIPIN has been proposed. This is based on the use of the Kiefner correlation between Charpy impact energy and fracture toughness, which is currently used in PIPIN. The estimated fracture toughness is then reduced by a specified factor to account for the effect of hydrogen. The toughness retention factors depend on pipe strength grade, while installation decade is also inherently included.

Checks against a published data set on the fracture toughness of 22 pipeline and plate steels in 100 bar hydrogen showed that the mean predicted toughness using the developed method was 1.29 times the actual measured toughness. 55% of predictions were higher than the measured value by +20%.

The developed approach applies to estimations of failure frequencies for LUP purposes, where the condition of the pipe is unknown. This means that the approach is not applicable to fitness-for-service assessments of existing pipes containing known or postulated damage. The level of conservatism in the proposed approach is therefore considered appropriate and reflects this difference.

One of the proposed modifications to PIPIN impacts the calculations of failure rates for substances other than hydrogen. A test set of 584 methane pipelines has therefore been run in the proposed model for both hydrogen and methane and the results have been compared against the current model. In addition, a set of non-natural gas pipelines has also been run in both models and the results compared. These tests indicate that there are minor differences in failure rates for substances other than hydrogen between the current and proposed model versions. The results have also been used in the calculation of LUP zones and it has been shown that the differences in the zone sizes are generally small (on average, a decrease in zone size for natural gas pipelines of less than 5%).

When the hydrogen results are compared to the methane results, it is shown that the failure rates are larger than for methane for all sizes in all bar one case, which sees a decrease in the large hole, small hole and pinhole results for hydrogen. This is as expected and an explanation is provided for the one anomalous result.

Executive Summary

Background

The Health and Safety Executive (HSE) uses a computer code, PIPIN (PIPeline INtegrity), to determine the failure frequencies of major accident hazard (MAH) pipelines. PIPIN calculates the failure rates of pipelines for various modes of failure, which are then used in other tools, such as MISHAP (Model for the estimation of Individual and Societal risk from HAzards of Pipelines). MISHAP calculates Land-Use Planning (LUP) zones around the pipeline, which are used to provide advice to local planning authorities on developments in the vicinity of the pipeline and when modifications to the pipeline are proposed.

PIPIN contains two approaches for the determination of failure rates. The first is based on operational experience data, the second is a predictive model that uses structural reliability techniques to predict the failure frequency due to third party activity (TPA). The model for TPA requires the fracture toughness of the pipeline steel as an input. This is known to be adversely affected by the presence of hydrogen and must therefore be modified for the PIPIN approach to be applicable to hydrogen pipelines.

Approach

The current report covers the potential effects of hydrogen on the fracture toughness, and other mechanical properties, of pipeline steels and makes proposals for the changes to the method to account for this. The appropriateness of the correlation between Charpy impact energy and fracture toughness, currently used in PIPIN, was evaluated. Reduction factors to account for the potential effect of hydrogen on the fracture toughness of pipeline steels have been developed, taking account of pipeline grade and decade of installation. The approach was then evaluated against existing data on the fracture toughness of pipeline steels in hydrogen to determine its suitability. The potential effects of hydrogen on pipeline mechanical properties used in other failure modes within PIPIN have also been considered.

The proposed changes impact on all substances, as well as hydrogen. The effects of the changes on the model predictions have been assessed for several substances, and the results for hydrogen have been compared to those for methane for a set of 584 pipelines. In addition, the impact of the changes on the final LUP zones has been assessed for all substances other than hydrogen, as MISHAP is not currently capable of modelling hydrogen pipelines.

Conclusions

A stepwise approach for accounting for the effect of hydrogen on the fracture toughness of pipeline steels for use within PIPIN has been proposed. The proposed approach is based on the use of the Kiefner correlation currently used in PIPIN to estimate fracture toughness, which is then reduced by a specified factor to account for the effect of hydrogen. The toughness retention factors for hydrogen have been determined based on test data in the literature and vary from 0.35 to 0.50. The factor varies with pipe strength grade, which is somewhat dependent on installation decade based on which grades have been introduced in those decades. A correction to the Charpy impact energy is also made when this is determined from sub-size specimens.

Checks against a published data set on the fracture toughness of 22 pipeline and plate steels in 100 bar hydrogen showed that the mean predicted toughness using the developed method was 1.29 times the actual measured toughness. 55% of predictions were higher than the measured value by 20%.

Several other failure modes are covered within PIPIN beyond those associated with TPA; corrosion, mechanical failures and ground movement, which includes failures from other causes not captured in the other categories. As none of the mechanical properties of pipeline steels that are adversely affected by hydrogen form inputs for these analyses within PIPIN, a change to the calculated failure frequencies for these failure modes would not be expected when using this code.

The analysis presented in this report applies to estimations of failure frequencies for LUP purposes, where the condition of the pipe is unknown. The approach is not applicable to fitness-for-service determination for existing pipes containing known or postulated damage. The level of conservatism in the proposed approach is therefore considered acceptable and reflects this difference.

When the proposed version of PIPIN is run for a representative set of pipelines and compared to the current version, it is found that the failure rates are reduced slightly in all cases. This leads to a reduction in the LUP zones in some scenarios. When the hydrogen results are compared to those for natural gas, it is found that the failure rates are higher, as would be expected, in all bar one case. The exception has increased rupture failure rates but reduced rates for the various hole sizes modelled, when compared to natural gas. This anomaly is explained by the relative importance of each of the sub-models in PIPIN for this scenario, some of which are unaffected by the presence of hydrogen.

Contents

1 Introduction

1.1 Background

The Health and Safety Executive (HSE) uses a computer code PIPIN (PIPeline INtegrity) (Chaplin, 2015a) to determine the failure frequencies of major accident hazard (MAH) pipelines. PIPIN calculates the failure rates for various categories of failure of pipelines, which are then used in other tools, such as MISHAP (Model for the estimation of Individual and Societal risk from HAzards of Pipelines) (Chaplin, 2015b). MISHAP calculates the level of risk posed to people by MAH pipelines and is used to set land use planning (LUP) zones around them. The LUP zones are used by planning authorities to aid in planning decisions for proposed developments near a pipeline, modifications to the pipeline, or for new pipelines. PIPIN contains two approaches for the determination of failure rates. The first is an approach based on operational experience data, which generates failure rates for four principle failure modes:

- Mechanical failures
- Natural events
- Corrosion
- Third party activity

The second approach is a predictive model that uses structural reliability techniques to predict the failure frequency due to third party activity (TPA) only. This calculated value for TPA is used in the model in preference to the operational experience derived value. The current report focusses predominantly on this latter model and considers the modifications necessary to the material property inputs to enable the PIPIN model to be applied to pipelines conveying gaseous hydrogen. The TPA predictive model includes three sub-models:

- A gouge model that models the plastic collapse of the pipeline using either gouge data or dent-gouge data
- A dent-gouge model that models failure of the pipeline by fracture; and
- A rupture model that models the likelihood of a leak leading to a rupture, resulting from either of the above failures and using either gouge or dent-gouge data

The potential changes to inputs for these models for pipelines carrying hydrogen, rather than natural gas or other hydrocarbons, must be considered as part of the revision of the PIPIN model for hydrogen pipelines. In particular, the current report covers the potential effects of hydrogen on the mechanical properties of pipeline steels and any associated changes to the method that may be required to account for this.

1.2 Approach and context

In the current report, the material properties used within the three sub-models of the third party activity (TPA) model are considered in combination with the potential effects of hydrogen and the expected magnitude of any change in these properties. The principal mechanical property evaluated is the fracture toughness of the pipeline steel. The appropriateness of the correlation between Charpy impact energy and fracture toughness, currently used in PIPIN, is evaluated. Reduction factors to account for the potential effect of hydrogen on the fracture toughness of pipeline steels have been developed. The approach is then evaluated against existing data on the fracture toughness of pipeline steels in hydrogen to determine its suitability. The potential effect of hydrogen on pipeline mechanical properties used in other failure modes within PIPIN are also considered.

The PIPIN model is used to predict failure frequencies for major accident hazard (MAH) pipelines. The failure frequencies generated are used as part of the calculation of land use planning (LUP) zones around the pipeline, which are then used by planning authorities to assess proposed developments near a pipeline, modifications to it or routing for new pipelines. The analysis presented in this report applies to estimations of failure frequencies for LUP purposes, where the condition of the pipe is unknown and to provide a guide on relative failure frequencies. The approach is not applied to the case of an existing pipe containing known damage, or a damage scenario for a section of pipeline. The level of conservatism in the proposed approach reflects this difference.

2 Failure modes within the PIPIN model

2.1 Modes covered

PIPIN V3 contains three fracture-mechanics based models for the assessment of failure frequencies due to third party activity (Chaplin, 2017):

- A gouge model that models the plastic collapse of the pipeline using either gouge data or dent-gouge data
- A dent-gouge model that models failure of the pipeline by fracture; and
- A rupture model that models the likelihood of a leak leading to a rupture, resulting from either plastic collapse or fracture

For the first of these, the required material properties are the yield strength (YS) and ultimate tensile strength (UTS), while for the second and third the fracture toughness of the material is also required. This is then applied in a fracture mechanics methodology, which assesses the failure risk in terms of fracture and plastic collapse using a Monte Carlo method. The fracture toughness used in the model is that based on quasi-static loading, since the model accounts for potential fracture from the resultant TPA damage, not the TPA event itself.

Experimental test data for tensile properties of pipeline steels in hydrogen environments show that yield strength and ultimate tensile strength of most pipeline grades are little affected by hydrogen (Gallon, 2020) (Somerday, 2012) (Bannister, Chaplin, & Gant, 2020). Consequently, the material properties inputs of the existing PIPIN fracture-mechanics based models which use these parameters as inputs do not need modification for application to hydrogen pipelines.

Conversely, the required inputs for the dent-gouge and rupture models include fracture toughness of the steel pipeline. This material property is known to be affected by the presence of hydrogen, as also reported in the previous references, and must therefore be modified for the PIPIN approach to be applicable to hydrogen pipelines.

In all cases, to determine whether a particular pipeline will fail or not, use is made of the Failure Assessment Diagram (FAD). In PIPIN, the CEGB R6 Rev 3 (CEGB, 1996) method is used. The FAD is suitable for assessing the significance of crack-like flaws in a pressurised steel component. The potential for failure from a flaw due to brittle fracture and plastic collapse can be determined using this method. It is a two-parameter approach which gives a graphical representation of the flaw condition with respect to the combined effects of both failure modes. The flaw is predicted to be safe, unsafe or on the boundary between the two (‘critical’) for the particular set of input data such as flaw, stresses and material properties. The shape of the FAD, accounts for the interaction of fracture and yielding, as well as work hardening of the material at stresses slightly above yield.

The plastic collapse parameter, *Lr*, is the ratio of net-section stress to the yield or proof stress of the material. The maximum value of *Lr*, representing the cut-off to the FAD, is a function of the YS/UTS ratio of the material. The brittle fracture parameter, *Kr*, is the ratio of the applied stress intensity, *K*, to the fracture toughness, K_{IC}. The K_{IC} is ideally measured on representative materials with conditions such as temperature and loading rate appropriate to the expected service conditions. In the absence of such data, the fracture toughness can be estimated from the Charpy impact energy characteristic of the material.

BS 7910 (BSI, 2019a) is a comprehensive standard for the determination of the acceptability of flaws in metallic structures which is commonly used for non-nuclear applications instead of the R6 method. The current version of the standard is 2019, and certain parts of the fracture assessment sections of this standard are equivalent in concept to the CEGB R6 method.

In PIPIN, the pipe grade, diameter and thickness are required. The pipe grade includes minimum requirements for YS, UTS and Charpy impact energy, the last at a defined test temperature. As fracture toughness testing is not a required material release test for steel pipeline manufacture, it is necessary to infer this from the Charpy impact energy requirement for the pipe grade. Numerous correlations are available for this and have been studied extensively since the 1970s.

2.2 Fracture toughness estimation from Charpy impact energy within PIPIN

2.2.1 Charpy impact energy

The Charpy impact test, also known as the Charpy v-notch test, is a standardised high strain-rate test widely used as a measure of toughness for steel products. The test involves an impact of a notched bar of standard dimensions, normally of cross-section 10 mm × 10 mm, at a specified temperature which is generally less than room temperature. Three repeats are usually made at a specific test temperature, with a minimum mean requirement for Charpy energy defined for the particular steel type and grade. Charpy impact energy varies with temperature for steels such as API pipeline grades and such materials undergo a transition from ductile to brittle behaviour as the temperature is reduced. This is termed the ductile-brittle transition temperature (DBTT). A schematic of the variation of Charpy impact energy with temperature is shown in Figure 1. It should be noted that a given grade tested at the specified temperature may yield energies far above the minimum requirement. In the example given, the energy at 0°C is approximately 200 J. Steel composition, rolling schedule and thermomechanical treatment will greatly affect the achievable Charpy impact energy. Modern steels will therefore generally show far superior impact energies to those manufactured in e.g. the 1960s and 70s.

Conventional test requirements for pipeline steels to both API (API, 2020) and BS EN ISO (BSI, 2019b) standards include energies of either 27 J or 40 J at a test temperature of 0°C, with higher energies required for higher strength grades and larger diameters. The Charpy impact test is easy to prepare and conduct and represents a low-cost method for a comparative basis of the impact toughness of steels. However, it cannot be used directly in fitness-for-service methods such as (CEGB, 1996) (BSI, 2019a). In the absence of toughness data, correlations must therefore be used to convert from the Charpy impact requirement for the grade, to an estimated fracture toughness.

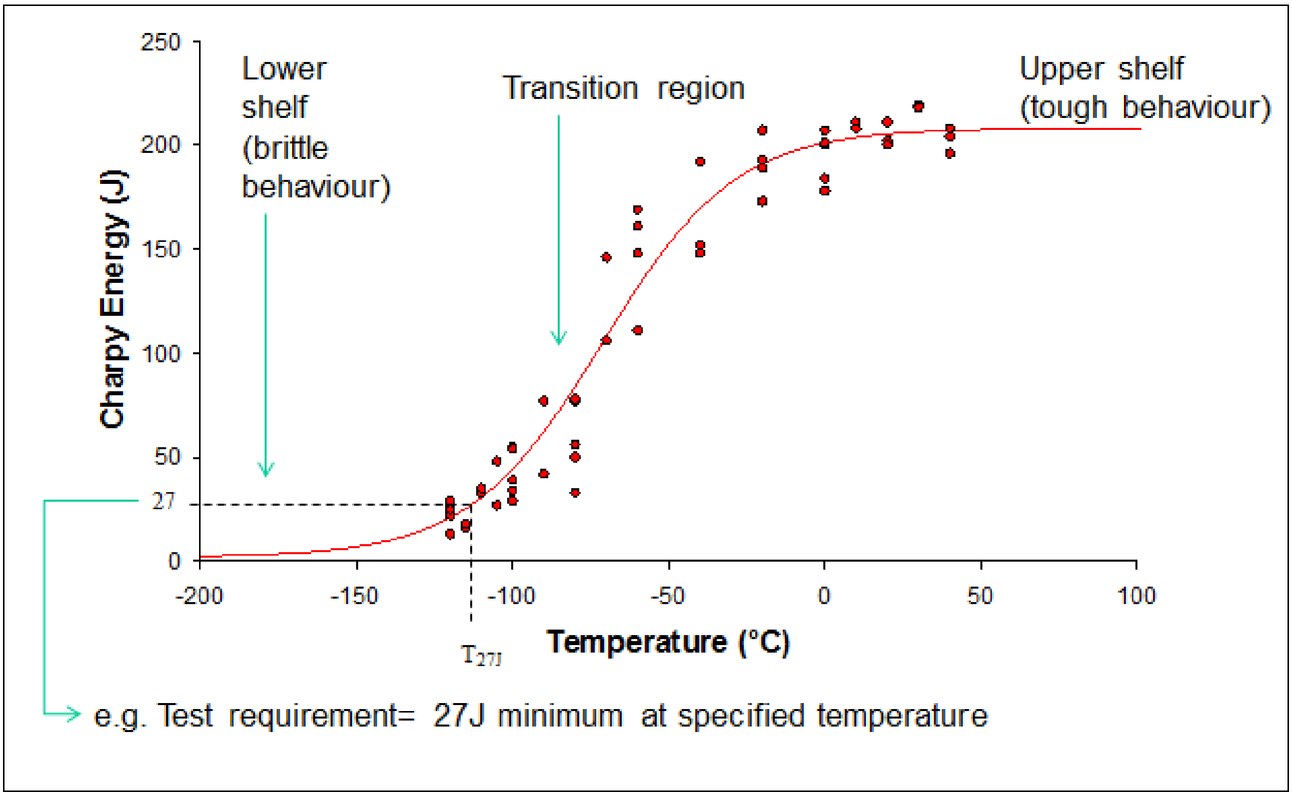

Figure 1: Schematic of Charpy impact energy transition curve for ferritic steels

2.2.2 Charpy–fracture toughness correlation used within PIPIN

The correlation between Charpy impact energy and fracture toughness currently used within the PIPIN model is that by Kiefner et al (Kiefner, Maxey, Eiber, & Duffy, 1973). This correlation was developed based on the results of 92 burst tests on pipeline sections containing artificial axial through-wall flaws. The strain energy release rate measured in the tests, G, was used as the comparative energy measure for empirical correlation against the relative energy (energy per unit area of specimen ligament) in the Charpy test. The resulting correlation is:

$$K_{IC} = \sqrt{\frac{12CVN \times E \times 0.08334 \times 1000}{A_c}} \quad (1)$$

In the above equation:

- K_{IC} = Fracture toughness in air/ ambient environment (MPa√m)
- *CVN* = Minimum specified mean Charpy v-notch impact energy at 0°C for a full size (10 mm × 10 mm) specimen (Joules)
- *E* = Young's modulus for steel pipe material= 208 (GPa)
- A_c = Ligament area of a full size Charpy specimen= 80 (mm^2)

This is the same equation as in the original PIPIN model. However, the definitions of *CVN* and A_c are slightly different. These have been modified from the original definitions in PIPIN to correspond with those of the original intention of the Kiefner expression, and represent the values for the case of full size, 10 mm × 10 mm, Charpy specimens. The Kiefner expression accurately represents the results of the original pipeline test series and has continued in use to the present day (Mohitpour, Seevam, Botros, Rothwell, & Ennis, 2012), although minor modifications have been proposed for high-strength materials with high toughness. For example, for a Charpy impact energy of 27 J in a full size specimen, equation 1 gives a fracture toughness of 265 MPa√m. Taking the original definitions of *CVN* and A_c from PIPIN gives a slightly lower fracture toughness of 238 MPa√m, indicating that the slight error in the original PIPIN is conservative, underestimating the fracture toughness by 10%.

The Charpy impact test temperature for pipeline steels in API 579 and EN ISO 3183 is 0°C. The standard operating temperature in the UK for buried pipelines is taken as +5°C and the minimum pipeline operating temperature is taken as 0°C, as per IGEM/TD/1 (IGEM, IGEM/TD/1 Edition 5: Steel pipelines and associated installations for high pressure gas transmission, 2010). Where the operating or design temperature is higher than these values, no additional consideration is required and there will be an additional level of conservatism.

Where the operating or design temperature is lower than 0°C, an additional reduction in Charpy impact energy will be necessary and the calculated toughness will be correspondingly lower. Such occurrences should be assessed on a case-by-case basis. It should be noted, however, that it is generally assumed in PIPIN that the fluid temperature is 5°C and so this is unlikely to be an issue.

2.3 Other Charpy-fracture toughness correlations

There are a large number of Charpy-fracture toughness correlations in existence for ferritic steels such as API pipeline grades, and several compilations of these have been published. However, many of these have largely been superseded by the 'Mastercurve' approach, now adopted in BS7910 (BSI, 2019a). In the absence of fracture toughness data, this standard allows the estimation of the fracture toughness from the Charpy impact energy characteristic of the material. Annex J of BS7910 describes suitable approaches for this, and presents a number of correlations:

- Lower bound estimation for near lower shelf (brittle) behaviour based on a specific Charpy impact energy

- A correlation for transitional behaviour based on a specific reference transition temperature of T_{27J} or T_{40J}
- An equation for limiting the calculated K_{IC} to avoid overestimation for materials with low upper shelf energies
- A temperature shift for the case of Charpy data determined on sub-size specimens

The near-lower shelf equation, equation 2, is recommended for use in IGEM/TD/1 hydrogen supplement (IGEM, 2021):

$$K_{mat} = \left[\left(12\sqrt{C_v} - 20\right)\left(\frac{25}{B}\right)^{0.25}\right] + 20 \qquad (2)$$

Where:

- K_{mat} = The material's fracture toughness (MPa√m)
- C_v = Minimum Charpy impact energy at the service temperature for energies between 3 J and 27 J and greater than 80% crystallinity on the fracture surface (i.e. brittle behaviour) (J)
- B = Section thickness in the plane of the flaw (mm)

This expression tends to give very conservative (i.e. low) estimates of fracture toughness. A more complex equation is also provided which is based on the relationship between the relative positions of specific reference temperatures on the Charpy and K_{mat} transition curves for ferritic steels, known as the Mastercurve:

$$T_0 = T_{27J} - 18°C\ (standard\ deviation = 15°C) \qquad (5)$$

$$T_0 = T_{40J} - 24°C\ (standard\ deviation = 15°C) \qquad (4)$$

$$K_{mat} = 20 + \{11 + 77exp[0.019(T - T_0 - T_K)]\}\left(\frac{25}{B}\right)^{0.25}\left[ln\left(\frac{1}{1-P_f}\right)\right]^{0.25} \qquad (3)$$

Where:

- T_{27J} and T_{40J} are the 27 J and 40 J transition temperatures on the Charpy transition curve for the steel using full-thickness samples, being typical requirements of steel specifications
- K_{mat} = The material's fracture toughness (MPa√m)
- T_0 = Temperature for a median toughness of 100 MPa√m in 25 mm thick specimens
- T = The temperature at which the fracture toughness is to be determined (°C)

- T_K = A term describing the scatter in the correlation, taken as 25°C
- *B* = Section thickness in the plane of the flaw (mm)
- P_f = Probability factor, where P_f= 0.5 represents the mean (50% chance of exceedance) and P_f = 0.05 represents a lower estimate such that the estimated fracture toughness has a 95% chance of being exceeded in actual fracture toughness tests.

In equations 2 and 5, the material's thickness appears as a denominator. This reflects the influence of increasing thickness on crack tip constraint, such that for lower shelf behaviour, a thicker material will produce a lower fracture toughness. Conversely, for upper shelf (ductile) behaviour the reverse effect is true.

P_f = 0.05 is recommended in annex J of BS7910 for use with equation 5 unless experimental evidence supports the use of a higher probability. The selection of P_f =0.05 generally results in very low estimates of fracture toughness (95% probability of exceedance). While this is appropriate for a first level fitness-for-service assessment of a structure containing a known flaw, it leads to highly pessimistic estimates of toughness for other more generic assessments.

2.4 Comparisons of estimated fracture toughness from different correlations

In 2009, an independent evaluation of the basis, assumptions and equations used within the PIPIN model was carried out (Francis, 2009). This included commentary on the suitability of the Kiefner correlation used in PIPIN, and states that this overestimates the fracture toughness by a considerable margin. However, the fracture toughness predicted from this correlation was not compared with actual measured values in this study, so the statement is not supported by data.

The use of correlations from BS7910 was suggested as an alternative. As BS7910 is predominantly a method for fitness-for-service evaluation of existing or postulated flaws in structures, the correlations for predicting toughness must necessarily be conservative. The premise of BS7910 is that where an initial screening analysis of a structure produces a highly conservative outcome, one must move to higher levels of analysis with correspondingly more precise data if the initial outcome is unacceptable. Fracture toughness testing of actual material representing the component will generate more accurate and less conservative results in a BS7910 or R6-type analysis.

A comparison of the predicted fracture toughness using equations 1, 2 and 5, the last with three levels of P_f, is given in Table 1. Two pipeline thicknesses are considered (12.5 mm and 25 mm), and two typical minimum Charpy energy requirements (27 J and 40 J). The thickness applies only to equations 2 and 5, while the probability of failure (P_f) only applies to equation 5.

Table 1: Comparison of predicted fracture toughness values using Kiefner and BS7910 expressions

Correlation	Equation No.	Charpy impact energy at 0°C (J)	Thickness (mm)	P_f	Fracture toughness (K_{IC}) at 0°C (MPa√m)
Kiefner	1	27	12.5	n/a	265
BS 7910 J.1	2			n/a	70
BS 7910 J.5	5			0.05	64
				0.5	105
				0.95	143
Kiefner	1	40	12.5	n/a	323
BS 7910 J.1	2			n/a	87
BS 7910 J.5	5			0.05	69
				0.5	114
				0.95	163
Kiefner	1	27	25	n/a	265
BS 7910 J.1	2			n/a	62
BS 7910 J.5	5			0.05	57
				0.5	92
				0.95	123

The above results show that for specified minimum Charpy impact energies of 27J and 40J:

- The use of the Kiefner expression gives fracture toughness values in the range 265 to 323 MPa√m
- BS7910 equation J.1 gives fracture toughness values in the range 62 to 87 MPa√m
- BS7910 equation J.5 with P_f = 0.5 (median correlation) gives fracture toughness values in the range 92 to 114 MPa√m
- BS7910 equation J.5 with P_f = 0.05 (lower bound correlation) gives fracture toughness values in the range 57 to 69 MPa√m
- BS7910 equation J.5 with P_f = 0.95 (upper bound correlation) gives fracture toughness values in the range 123 to 163 MPa√m

For a Charpy impact energy of 27 J the values derived from BS7910 equation J.5, range from 92 to 105 MPa√m for a median fit and 57 to 64 MPa√m for the lower 5th percentile fit. BS7910 recommends the use of the lower 5th percentile fit unless experimental evidence supports a higher probability. The toughness ranges determined using both probabilities are low compared to the generally expected values of fracture toughness of pipe body material of modern pipeline steels. Use of these correlations for estimating fracture toughness would be highly conservative, irrespective of the aims of the analysis. Similar observations are made in (Pisarski & Bezensek, 2019) in which the conservatism of this equation when predicting the toughness of pipeline steels is noted through comparison with actual test data.

3 Effect of Hydrogen on mechanical properties of pipeline steels

3.1 Required properties

3.1.1 Overview

Molecular hydrogen in gaseous form can dissociate into atomic hydrogen on metal surfaces, the small size of the atom facilitating its migration into the metal lattice where it can lead to hydrogen embrittlement. While there are many different terms used to describe hydrogen embrittlement in steels, ultimately, this manifests itself as a reduction in certain mechanical properties such as ductility and toughness. Strength and steel microstructure have an effect on sensitivity to hydrogen, with higher strength pipeline grades tending to show increased sensitivity to the effects of embrittlement. This increased sensitivity to hydrogen is not due to increased pressure but is due to the steel microstructure present in higher strengths. High strength steels such as X80 are relatively recent in steel plate processing, since older techniques could not achieve these strengths without adding other elements to the steel. These additional elements make the steel more susceptible to hydrogen embrittlement. Fracture toughness is reduced for most pipeline steel grades under both gaseous hydrogen and electrochemical (cathodic) charging conditions.

The effect of hydrogen on the tensile properties of pipeline steels has been extensively reported on. While the effect on yield strength (YS) and ultimate tensile strength (UTS) is usually quite limited, hydrogen universally reduces the ductility (measured as percentage elongation to failure) of metals such as carbon-steels.

Sharp flaws in structures, such as weld defects or fatigue cracks, can be described by the stress intensity factor *K*[1]. Stresses are also elevated at corrosion pits and volumetric weld flaws, where cracks may initiate. In order to prevent fracture from such regions, the material must also possess sufficient fracture toughness. A frequently used measure of fracture toughness is the critical stress intensity factor, K_{IC}. Many empirical approaches for estimating fracture resistance of natural gas pipelines have been developed based on the Charpy impact energy. This is a relatively low cost test, being an impact test on a notched bar, and is used to qualify pipeline steels to the relevant specifications in place of the more complex and expensive fracture toughness test.

An inherent degree of conservatism exists when applying fracture toughness to pipelines. Most published fracture toughness values for pipeline steels are determined on deep-notched compact tension (CT) or Single edge notch bend (SENB) samples which provide a high level of constraint. Most pipelines are relatively thin walled but if any flaws are present, they are invariably small compared to the wall thickness. These conditions

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[1] The stress intensity factor is a measure based on the characteristics of sharp flaws such as fatigue cracks and is termed K. Fracture occurs when the applied K exceeds the material's fracture toughness, K_{IC}.

represent low constraint. Hence, when fracture toughness values are applied to pipelines they are invariably conservative, often significantly so. The use of Single edge notch tension (SENT) sample design may overcome this, but their use in hydrogen environments has not yet been established.

3.1.2 Relevance of Charpy test

The effect of hydrogen on Charpy impact performance of pipeline steels has been relatively little studied. Charpy impact tests on pre-charged samples of X65 pipeline steel showed minimal effect of the hydrogen charging on both ductile-brittle transition temperature (DBTT) and upper shelf energy (Fassina, et al., 2012). Under dynamic loading conditions, such as in the Charpy impact test, the hydrogen embrittlement of steels is minimal due to the limited hydrogen diffusion achievable over the short duration of this test.

The ‘true’ resistance of a material to the propagation of a crack is given by fracture toughness and not Charpy impact energy, as explained in Annex J of (BSI, 2019a) and (Andrews, Gallon, & Huising, 2022).Therefore, in the context of PIPIN, it is proposed that the fracture toughness in an ambient environment is first determined from the Charpy impact energy, followed by the application of a factor to this value to allow for the effects of hydrogen.

3.2 Data in literature on effect of hydrogen on fracture toughness[2]

3.2.1 Test data from Sandia National Laboratories

A comprehensive series of tests on ferritic steels has been carried out by Somerday (Somerday, 2012), published as an extensive compilation of historic and more recent test results. Various steel grades were tested at a range of hydrogen pressures. The overall observation was that fracture toughness is degraded by as much as 50% at a constant hydrogen pressure of 69 bar.

3.2.2 Compilation of pipeline toughness data in hydrogen (HSE)

In (Bannister, Chaplin, Gant, Spriggs, & Thomson, 2021), values for fracture toughness measured on pipeline steels in both ambient and hydrogen atmospheres were collated from literature, covering both gaseous hydrogen at various pressures and cathodically-charged conditions. The ratio of toughness in hydrogen to ambient atmospheres was then determined, summarised in Table 2. This shows the wide variation of retained toughness, with an overall mean across pipe grades X42 to X65 of 0.54.

[2] Fracture toughness in this context is the plane strain fracture toughness K. For tests on pipeline steels it is often determined from the J integral at a specified amount of tearing ahead of the crack tip. In the current work, the majority of test data referred to are based on the standard definition of J integral defined at 0.2 mm crack extension, termed $J_{0.2mm}$, as per ASTM E1820. Other definitions at lower amounts of crack extension also exist but are less conventionally used and more difficult to measure consistently.

Table 2: Retention ratios of fracture toughness in gaseous and cathodically-charged hydrogen environments (Bannister, Chaplin, Gant, Spriggs, & Thomson, 2021)

Grade	Mean ratio (Toughness H2/ Toughness air)	Range of ratios (Toughness H2/ Toughness air)	Number of test data
X42	0.48	0.22 to 0.90	17
X52	0.68	0.49 to 0.90	11
X60	0.62	0.35 to 0.96	7
X65	0.38	0.13 to 1.25	10
All grades	0.54	-	45

3.2.3 Results from Naturalhy

In NATURALHY (Van Wortel, et al., 2009), electrolytic charging was used in several cases as part of a test programme on the effects of hydrogen charging on fracture toughness. This showed less effect than other studies; the effect of hydrogen varying from zero to 40% loss of toughness for X52 and up to 20% loss of toughness in X70 grades. Results were also differentiated into 'pre-1975' and 'post-1975' grades. Greater sensitivity of a lower strength grade (X52) was observed in this study as compared to higher strength grades. This was attributed, not to the relative strength difference itself, but to the different periods of manufacture, the X52 grade being of older (1960s) manufacturing period. Metallurgical improvements in steels manufactured typically post- c1970, arose from a combination of improved steelmaking practices, the use of micro-alloy additions and the development of controlled rolling techniques for plate used to make pipe. In combination these gave a finer grain structure, reduced inclusion content and improved weldability for a given grade. This aspect is discussed further in section 4.5.

3.2.4 Compilation of pipeline toughness data in hydrogen (EPRG)

Gallon et al. (Gallon, 2020) in an extensive review for the EPRG (European Pipeline Research Group) notes that, while there is broad agreement that hydrogen decreases the fracture toughness of steels, the magnitude of the decrease is unclear. Most sources seem to agree on a reduction in the typical range of 35 to 70%. Some sources also report fracture toughness in hydrogen of less than the 55 MPa√m of ASME B31.12 (ASME, 2019). However, EPRG (Gallon, 2020) also note that the laboratory-measured values of fracture toughness are not necessarily representative of pipeline service. In particular, if rapid unstable crack propagation begins in a gaseous hydrogen environment, diffusing hydrogen may not keep pace with the growing crack. The time dependency of fracture toughness in hydrogen also makes the definition of toughness as a unique property difficult.

In addition, it is noted in (Andrews, Gallon, & Huising, 2022) that the majority of fracture toughness data in hydrogen was determined on deep-notch specimens rather than low-constraint test geometries preferred for pipeline applications such as SENTs (Single Edge

Notch Tension). Lower constraint may also reduce the level of hydrogen embrittlement as the localised plasticity at the crack tip is more diffuse. Hence, the derived values, based on high constraint fracture toughness tests, may be highly conservative when applied to more realistic pipeline cases.

Andrews et al. (Andrews, Gallon, & Huising, 2022), applied the observations of (Gallon, 2020) on reduction of fracture toughness in hydrogen to some example case studies using low (20 J) and high (150 J) Charpy impact energies. The lower Charpy energy material was converted to fracture toughness using equation J.1 from BS 7910 (eq. 2 in this report) and the high Charpy energy material using equation J.11 (not quoted in this report). A reduction in toughness of 50% was applied for hydrogen service. These gave values of fracture toughness in hydrogen of 35 MPa√m and 75 MPa√m respectively for the low and high Charpy energy. Regarding the conservatism of these derived values, it is noted in (Andrews, Gallon, & Huising, 2022) that a 50% reduction in fracture toughness may not be the worst case based on (Gallon, 2020). However, the assumed initial fracture toughness in these analyses was low due to the inherent conservatism of the Charpy to K_{IC} correlations in BS 7910.

3.2.5 Pipeline toughness in hydrogen blends

Kappes et al (Kappes & Perez, 2023) evaluated the issue of pipelines operating in hydrogen blends using the failure assessment diagram (FAD) approach. The authors note that fracture toughness (K_{IC}) is not a required test for API 5L pipelines, but that it could be estimated from Charpy impact energy values.The authors suggest that, for first stage calculations, the fracture toughness in hydrogen, K_{IH}, can be taken as 0.5 K_{IC}, where K_{IC} can be estimated from Charpy data. Using this factor for pipeline steels is stated as being a simple and conservative criteron for grades X42 to X70, but that it would not be conservative for higher grades or the heat-affected zones (HAZs) of welds. However, Xu (Xu, 2012) , testing a range of pipeline grades between X42 and X80, observed retention factors of 0.48 to 0.73, with the lowest ratio observed for X70 and the average ratio measured at 0.60. It is also noted in (Xu, 2012) that the weld metal and HAZs of pipeline steels tend to be nearer to that of the pipe body material in lower strength grades, but deteriorate more rapidly than the base metal for high strength grades.

3.2.6 Pipeline toughness retention factors in hydrogen

Brown and Larosa (Brown, 2022) (Larrosa, Alvarez, Blanks, & Ainsworth) carried out detailed analysis of the toughness retention in hydrogen of different pipeline grades at a range of test pressures. Three criteria were applied to the data: gaseous hydrogen charging; mode I[3] fracture toughness was measured and; reference data in air must be available. The embrittlement ratio ($K_{mat}\,H_2/\,K_{mat}\,air$) was then determined for each grade/pressure combination. The ratio is considered a useful approach since different measures of fracture toughness had been used across the various studies and different

[3] Mode I is the condition where the crack plane is normal to the direction of the applied load and is the most commonly used mode for standard fracture toughness tests.

specimen geometries/sizes may have been used. The individual measured values are therefore not useful for direct comparison. However, as all values were determined on high constraint (deep notch) samples, the difference between specimen types was considered negligible. The analysis generated 56 data points, shown as a function of test pressure in Figure 2.

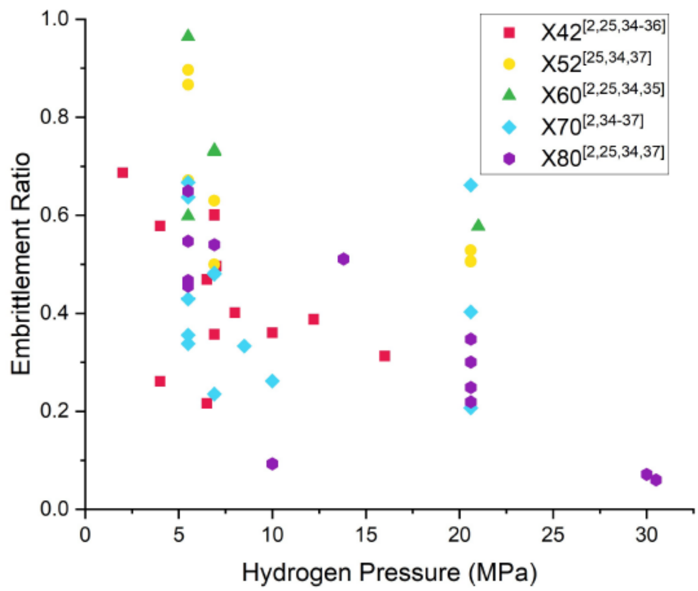

Figure 2: Embrittlement ratio (Toughness in hydrogen/ toughness in air) for all data evaluated in (Brown, 2022)

Curves were then fitted to this data, as shown in Figure 3 (Larrosa, Alvarez, Blanks, & Ainsworth). The solid lines show best estimates and the dashed lines are the 5% and 95% lower and upper bounds. It was assumed that the relationship was an exponential decrease tending towards a non-zero lower bound. This fits with the observations of many data sets where the presence of some hydrogen has an initially larger effect on reducing toughness from the ambient environment case as compared to further increasing the hydrogen level. It is noted that the curves for grades X42 and X70 are similar, whereas the general view is that higher strength grades will show greater reduction of toughness in hydrogen. However, lower strength grades have been manufactured since the 1950s, with increasing strength grades introduced over subsequent decades. Hence, older lower strength grades may have higher levels of carbon, higher levels of residual elements, and coarser grain size than modern higher strength grades. All three factors contribute to a lower fracture toughness.

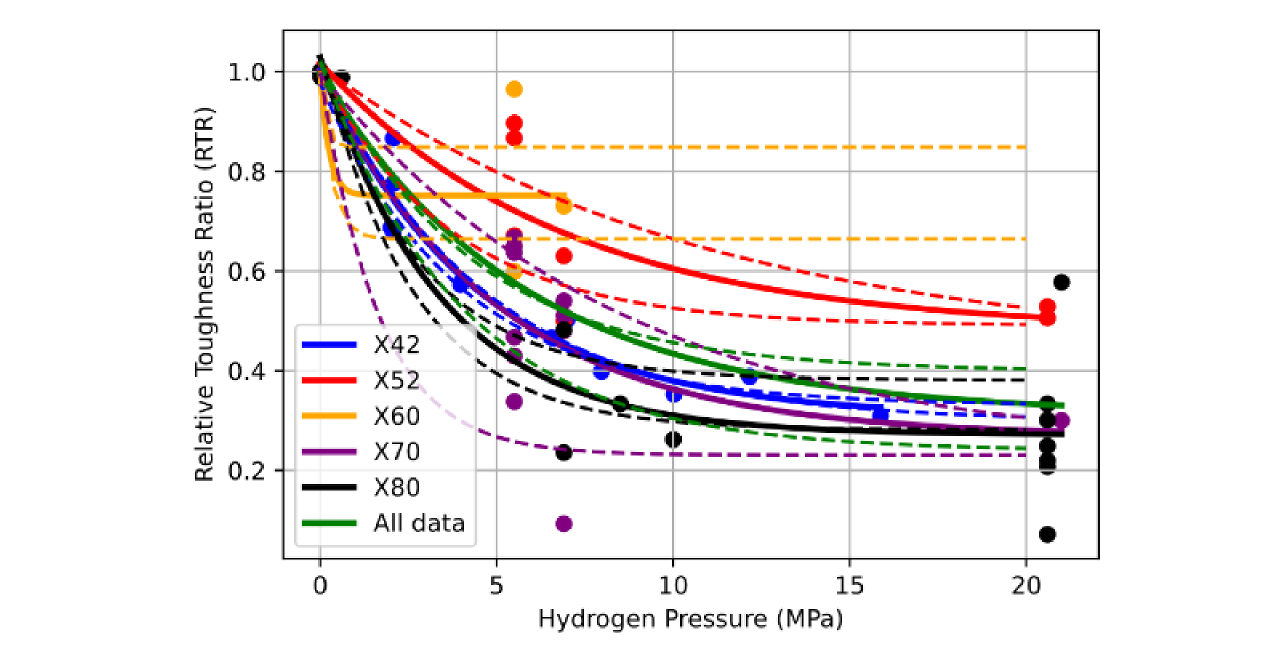

Figure 3: Fitted curves to toughness retention data shown in Figure 2 (Larrosa, Alvarez, Blanks, & Ainsworth)

3.2.7 Burkinshaw et al

Burkinshaw (Burkinshaw, Sandana, Gallon, & Bhatia, 2022) notes that different pipeline steels will have differing susceptibility to toughness degradation in hydrogen. While the increasing susceptibility with strength grade is appropriate as a rule of thumb, microstructural types and morphology will also influence the tendency to embrittlement. In this study, a statistical analysis was made of a ‘virtual network’ containing a range of pre-existing defects of varying size, with the toughness in hydrogen taken as 70%, 50% and 30% of values in air. Fracture mechanics assessments showed that the proportion of these features that would cause a failure in air was 1.1%, increasing to 3.8%, 11.7% and 34.7% when fracture toughness was factored to 0.7, 0.5 and 0.3 of the air value respectively.

4 Proposed approach for toughness definition for PIPIN for hydrogen

4.1 Overview

The proposed approach for determination of the value of fracture toughness in hydrogen is based on use of the Kiefner correlation currently used in PIPIN, reduced by a specified factor to account for the effect of hydrogen. The approach is based on Charpy impact energy for full size (10 mm × 10 mm) specimens. Where thin-walled pipe necessitates the use of sub-size Charpy specimens, equivalent full-size impact energies are used in the approach since correction factors are applied for this at the pipeline testing stage (API, 2020). A summary of the approach is given in Figure 4.

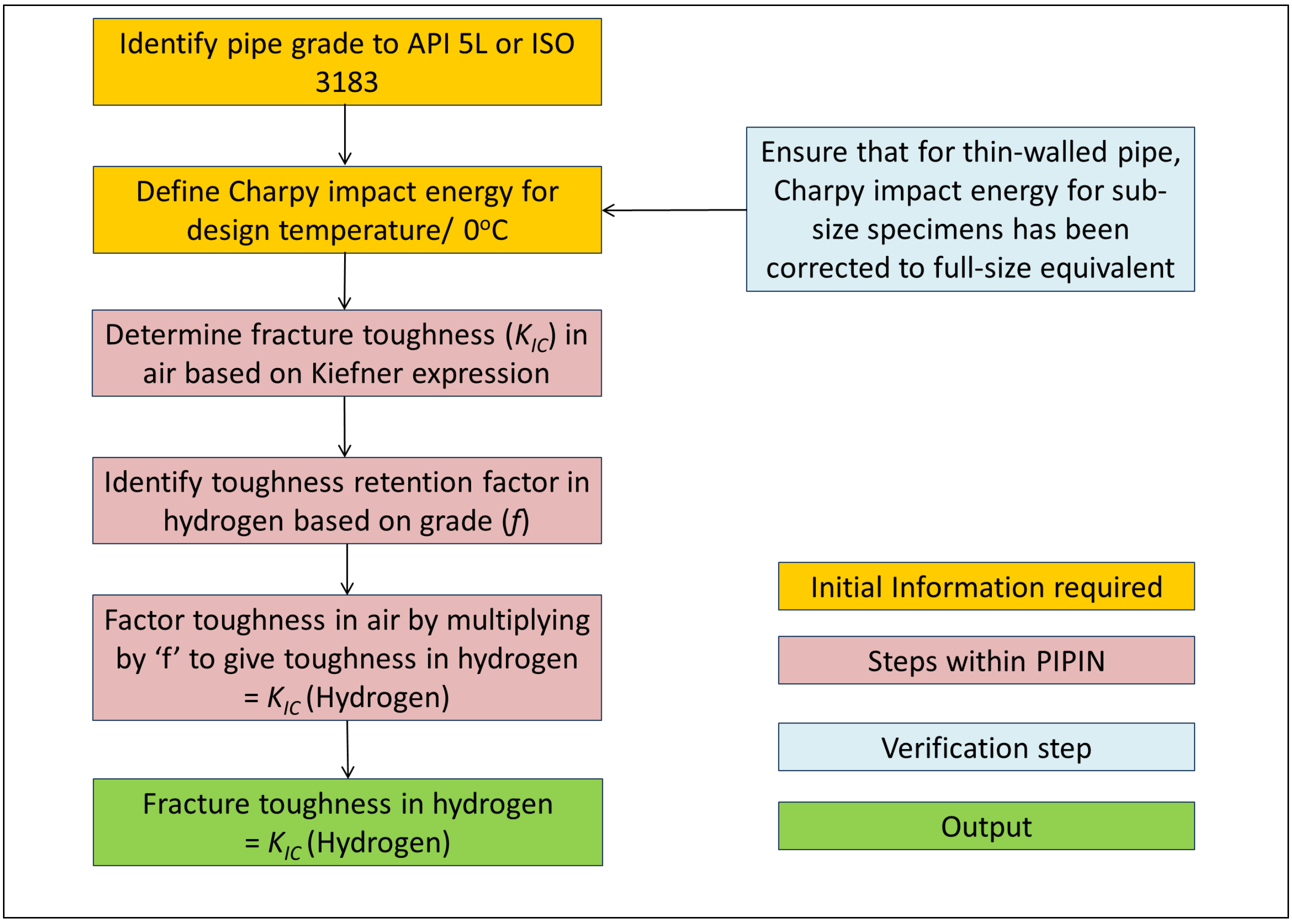

Figure 4: Flow chart of the proposed approach for determining fracture toughness in hydrogen

4.2 Charpy impact energy requirements for pipeline steels

Charpy impact energy is a key requirement for pipeline steels and is used as an indicator of fracture toughness. Values are given as energy in Joules (J) at a temperature in °C. Steel pipeline can be supplied to two specifications, BS EN ISO 3183 (BSI, 2019b) in Europe and API 5L (API, 2020) in the USA. The former grades are defined by the yield strength in MPa and the latter by the yield strength in Ksi.

Table 3: Equivalence of pipeline grades between BS EN ISO 3183 and API5L

ISO 3183	L245	L290	L320	L360	L390	L415	L450	L485	L555
API 5L	B	X42	X46	X52	X56	X60	X65	X70	X80

The Charpy impact requirements for full-size (10 mm × 10 mm) Charpy specimens for pipeline steels to the current version of BS EN ISO 3183 are listed below. Those for equivalent API 5L grades are the same.

- Grade B, X42, X46, X52, X56 and X60 inclusive:
  - 27 J at 0°C for diameters up to 762 mm
  - 40 J at 0°C for diameters greater than 762 mm
- Grade X65 and X70
  - 27 J at 0°C for diameters up to 762 mm
  - 40 J at 0°C for diameters greater than 762 mm but less than 1219 mm
  - 54 J at 0°C for diameters greater than 1219 mm
- Grade X80
  - 40 J at 0°C for diameters up to 1219 mm
  - 54 J at 0°C for diameters greater than 1219 mm but less than 1422 mm
  - 68 J at 0°C for diameters greater than 1422 mm

The above are the current Charpy test requirements; older pipelines (1970s, 1980s etc.) will have been installed to the earlier versions of the standards valid at the time and may be different. The table of Charpy values in Appendix B of HSE RR1037 (Chaplin, 2015a) is the minimum allowable value of three tests in the pipeline standards. A more usual approach is to define the Charpy impact energy as the mean of three repeat tests, as is done in a pipeline manufacturing environment. This should be taken as the reference energy for any subsequent estimation of fracture toughness. The current approach therefore differs slightly from the original PIPIN in this respect.

4.3 Correction for Charpy values determined on sub-size specimens

The Charpy requirements given in equation 1 and Section 4.2 are for full-size (10 mm × 10 mm) Charpy specimens. However, where the pipe wall thickness precludes a 10 mm thick specimen, thinner specimens of standard geometry may be used. If this is the case, a correction to allow for specimen size is applied at the testing stage. The thickness of the Charpy specimen can affect both the absorbed energy and the transition temperature. Generally, a thinner Charpy specimen will give a lower absolute level of absorbed energy in the Charpy test, due to the reduced cross-sectional area. However, the thickness can also affect the level of constraint at the notch tip in a similar manner to its effect on fracture toughness (see Section 2.3). Therefore the fracture transition between ductile and brittle behaviour will occur at lower temperatures in sub-sized Charpy specimens.

In BS7910 (BSI, 2019a) Annex J, sub-size Charpy data are treated by a shift in the transition temperature. However, in the case of PIPIN, the full Charpy impact transition curve is not available, only a specified value at a given test temperature as per the specification for the pipe material. Pipeline standards such as API 5L factor the energy required in a sub-size-Charpy specimen by the ratio of its cross-sectional ligament area to that of a full size specimen as shown in Table 4. For example, a 40 J requirement in a full-size specimen equates to a 30 J requirement in a 7.5 mm thick specimen. The impact values given in section 4.2 are applicable to all pipe thicknesses as the size correction factors will have been applied at the testing stage. They are included here for reference and to ensure the correct definition of impact energy is applied when using PIPIN.

Table 4: Impact energy correction factors for sub-size Charpy specimens

Charpy specimen size (thickness mm)	Divide Charpy energy by this factor to obtain equivalent sub-size impact energy
10.0	n/a
7.5	0.75
6.7	0.67
5.0	0.50
3.3	0.33
2.5	0.25

4.4 Determination of fracture toughness in ambient environment

The fracture toughness in ambient environment is estimated from the full-size Charpy impact energy requirement for the pipeline grade and size in accordance with the Kiefner equation used in PIPIN, which is given in equation 1.

4.5 Factoring of fracture toughness of pipeline steel grades in hydrogen

Based on the information presented in Section 3.2, toughness retention factors have been derived for steel pipeline materials operating in 100% hydrogen that are applicable to pressures up to 94 bar, the maximum operating pressure of the NTS (National Transmission System). The factors were established as typical values based on the published data for the fracture toughness in hydrogen as a proportion of the toughness in air for each pipe steel grade. The factor (*f*) is a retention factor, not a loss factor, i.e. a value of 0.4 indicates that the toughness in hydrogen is 40% of the value in air.

An assessment of the year of introduction of different pipe grades into API 5L in (Burkinshaw, Sandana, Gallon, & Bhatia, 2022), Figure 5, shows that grades A, B, C and X42 were the predominant grades up to around 1955; additional grades X46 and X52 were introduced around 1955; and X60 and above were introduced around1970. In the current approach, 1970 is taken as the reference point for significant improvement in pipe quality due to advances in steelmaking, plate rolling and pipe manufacturing. Grades B and X42 tended to be used less once higher strengths had been introduced. These two grades are considered to be vintage grades and are therefore assigned lower toughness retention factors in hydrogen.

Higher strength grades also tend to show greater sensitivity to degradation by hydrogen, an example being the higher diffusivity of hydrogen in acicular ferrite (Laureys, et al., 2022), a common microstructure in some higher strength pipeline steels. Grades X70 and X80 have therefore also been assigned lower toughness retention factors. It is noted in (Laureys, et al., 2022) however, that the same grade manufactured in different decades may have very different microstructures. Caution is recommended in (McAllister, Wright, & Bussiere, 2024) in terms of applying generally applicable ‘knockdown factors’[4] for the effect of hydrogen on toughness due to the effects of manufacturing vintage, hardness and microstructure. The proposed fracture toughness retention factors (*f*) is reduced to account for steel grades more likely to have been manufactured before the 1970s..

A potential overlap between strength grades, particularly in the past when there was no upper limit on yield strength, is noted but as PIPIN is based on grade alone it is not possible to account for this possibility.

[4] An alternative term used for the factored loss of toughness in pipeline steels due to hydrogen

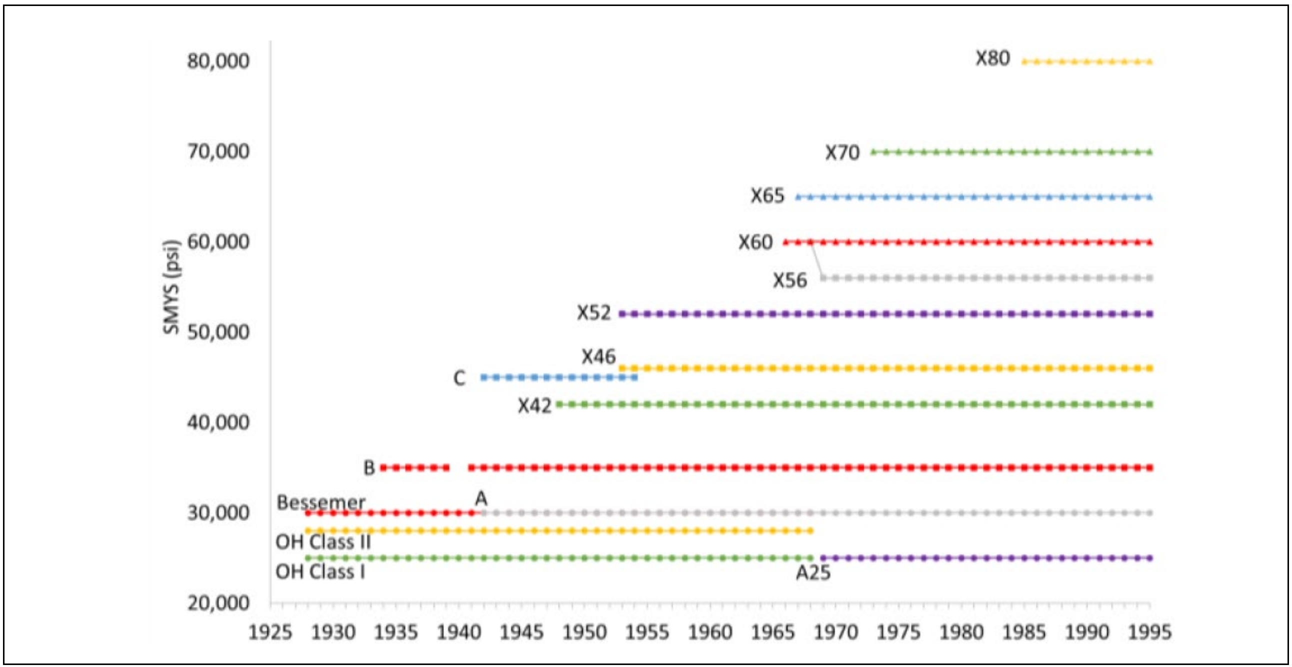

Figure 5: Years in which current pipe grades were introduced into API 5L (Burkinshaw, Sandana, Gallon, & Bhatia, 2022)

The toughness retention factors for use with steel pipeline grades for the PIPIN model as applied to pipelines conveying 100% hydrogen are as shown in Table 5. The following should be noted:

- Fracture toughness in air is first estimated through the use of the appropriate correlation from Charpy impact energy
- The fracture toughness in air is then multiplied by the given factor (*f*) to obtain an estimate of the fracture toughness in hydrogen
- Where the pipeline grade is not known, the retention factor should be taken as 0.35
- While vintage and high strength grades have lower retention factors, the proportion of these making up the gas network is significantly less than all the other grades combined
- The controlling factor is largely the steel microstructure and its response to hydrogen, rather than the grade itself. Since certain strength levels can only be achieved by certain microstructures, the two are implicitly related
- There can be overlap between strength grades. Earlier editions of the pipeline standard did not have an upper limit to yield strength, while more recent ones do
- The factors can be applied to blends containing less than 100% hydrogen with increased conservatism

Table 5: Fracture toughness retention factors for pipelines transporting 100% hydrogen

API 5L Grade	BS EN ISO 3183 grade	Toughness retention factor in hydrogen (f)	Commentary
B	L245	0.40	Vintage grades; show higher sensitivity to hydrogen
X42	L290	0.40	
X46	L320	0.50	Commonest grades; medium strength; Tend not to be of oldest vintage
X52	L360	0.50	
X56	L390	0.50	
X60	L415	0.50	
X65	L450	0.50	
X70	L485	0.40	High strength: may show high sensitivity
X80	L555	0.35	
Unknown	Unknown	0.35	For use when grade is not known

4.6 Upper limit on fracture toughness

The correlation used within PIPIN (Kiefner (Kiefner, Maxey, Eiber, & Duffy, 1973)) is open-ended and as such there is no upper limit to the predicted fracture toughness. K_{IC} does not, however, increase indefinitely with Charpy impact energy and there is a natural upper limit to toughness. This depends on many factors including the composition and process route of the pipeline steel, the test temperature, the pipe wall thickness and the specimen design. Both composition and process route for pipeline steels have improved over the decades, and as such, modern steels tend to give higher toughness levels than older steels of equivalent grade.

The Kiefner correlation within PIPIN is based on the use of the minimum specified Charpy impact energy for the given pipe grade and diameter. The predicted values therefore have a natural upper limit which is consistent with the levels of toughness achieved in typical pipeline steels. There is a diminishing effect of increasing toughness, predicted from higher Charpy energies, when using the failure assessment diagram (FAD). At higher toughness levels the analysis points tend towards the plastic-collapse (Lr) dominated region of the FAD where the result is less sensitive to toughness. The failure frequency tends towards a constant value as the Charpy energy increases towards 54 J.

It is therefore neither feasible nor necessary to apply an upper limit to fracture toughness in the current context.

5 Comparison with other approaches

5.1 Estimation of fracture toughness in hydrogen using other approaches

5.1.1 IGEM TD/1 and IGEM/TD1 hydrogen supplement

IGEM TD/1 (IGEM, IGEM/TD/1 Edition 5: Steel pipelines and associated installations for high pressure gas transmission, 2010), and its accompanying hydrogen supplement (IGEM, 2021), include requirements to ensure adequate pipeline toughness to prevent fracture. The normal operating temperature for the majority of buried UK pipelines is stated (IGEM, IGEM/TD/1 Edition 5: Steel pipelines and associated installations for high pressure gas transmission, 2010) as being greater than 5°C, and that the minimum design temperature should be taken as 0°C. Materials should have adequate toughness at, or below, the minimum design temperature. The minimum design temperature of above-ground pipework is usually taken as -10°C, however materials that are impact tested at 0°C and have a wall thickness of 20 mm or less may be used at design temperatures down to -10°C. API 5L and BS EN ISO 3183 are referenced as suitable applicable pipeline specifications. The current work in the context of PIPIN focusses on below ground pipelines only.

The IGEM hydrogen supplement to TD/1 (IGEM, IGEM/TD/1 Edition 6 Supplement 2; High Pressure hydrogen pipelines, 2021) requires that the Charpy impact and drop weight tear test (DWTT) requirements for natural gas pipelines shall be applied to pipelines intended for hydrogen service. The effect of hydrogen on the fracture propagation transition temperature and the upper shelf Charpy impact energy shall be established. However, it is noted that while the fracture toughness in hydrogen may be significantly lower, the loading rate in the Charpy impact test may be too high for hydrogen to cause a significant reduction in toughness. This is associated with the diffusion-controlled nature of hydrogen embrittlement at a crack or notch tip. Consequently the Charpy test will underestimate the toughness in hydrogen and conventional quasi-static toughness tests are preferred.

In the absence of testing, the fracture toughness in hydrogen service in (IGEM, 2021) shall be estimated using full-size equivalent Charpy impact energy equal to the lower of 50% of the specified value and 27 J. The correlation between fracture toughness and Charpy v-notch energy for steel exhibiting near lower shelf behaviour given in Annex J of BS 7910-2019 (BSI, 2019a) shall be used to estimate the fracture toughness, given as equation 2 in the current report.

5.1.2 ASME B31.12 Hydrogen piping and pipelines

The 2019 version of ASME B31.12 (ASME, 2019) provides detailed requirements for ensuring sufficient toughness of materials for pipeline applications. Option A is termed ‘Prescriptive Design Method’ and is based on the inference of performance from Charpy impact testing. Requirements are divided into those for brittle fracture and those for ductile fracture.

To ensure that the pipe has adequate resistance to brittle fracture, testing shall be performed in accordance with the procedures of Annex G of API 5L. To ensure ductile fracture arrest, the API 5L testing requirements are also required, with the Charpy impact test temperature the lower of 0°C or the lowest expected metal temperature during service. The average of the Charpy energy values from each cast shall meet or exceed the requirement of:

$$CVN = 0.008(RT)^{0.39}{\sigma_h}^2 \quad (6)$$

Where:

- *CVN* = Full-size specimen Charpy energy (ft-lb)
- *R* = Radius of pipe (inches)
- *T* = Nominal pipe wall thickness (inches)
- σ_h = Hoop stress due to the design pressure (ksi)

Applying equation 6 in metric units to an X60 grade pipe with diameters 500 mm and 1000 mm, wall thickness 5 mm, 10 mm and 25 mm and two levels of hoop stress provides the required Charpy impact requirements shown in Table 6.

Table 6: Required Charpy impact properties for ductile fracture arrest in X60 grade pipe in accordance with Option A of ASME B31.12 (ASME, 2019)

Pipe diam. (mm)	Wall thick (mm)	Grade	SMYS for grade (MPa)	Hoop stress as% of SMYS	Required CVNE (J)	BS EN ISO 3183 Charpy specification for design temperature of 0°C
500	10	X60	415	0.5	17	27J @ 0DegC
1000					22	27J @ 0DegC
500	5				13	27J @ 0DegC
1000					17	27J @ 0DegC
500	25				24	27J @ 0DegC
1000					31	40J @ 0DegC
500	10			0.75	37	40J @ 0DegC
1000					49	54J @ 0DegC
500	5				28	30J @ 0DegC
1000					37	40J @ 0DegC
500	25				53	54J @ 0DegC
1000					70	68J @ 0DegC

Option B of ASME B31.12 invokes the requirement to test representative pipeline materials in hydrogen to measure the threshold stress intensity factor in hydrogen, termed K_{IH}. This must be equal to or higher than the calculated required value of K_{IA}. K_{IA} is based on the stress intensity factor required for non-propagation of a postulated crack of depth *t/4* and length *1.5t*, where *t* is wall thickness, with the pipeline at its design pressure. In all cases, K_{IH} shall not be less than 55 MPa√m. Pipeline materials for Option B must also meet the requirements of API 5L PSL2. ASME B31.12 is currently being revised, but at the time of writing the new version has not been issued.

5.1.3 API 579 Fitness for service assessment standard

API 579 (API, 2021) is a comprehensive fitness-for-service assessment method applicable to a range of pressure containing equipment. The standard has broad application and covers a wide range of damage modes including brittle fracture. Although it is not specific to pipelines, Annex 9-F in this standard includes methods for estimating fracture toughness from Charpy impact energy. Most of these require more comprehensive information than the minimum specified energy at a specified test temperature and are largely based on the relative difference between the material's design temperature and the Charpy transition temperature.

In API 579, it is recommended that fracture toughness estimated from Charpy impact energy should be truncated at 110 MPa√m for materials with unknown composition, and

220 MPa√m for low sulphur steels. In an introductory paper to API 579 (Anderson & Osage, 2000), it is suggested that the above two limits for maximum predicted fracture toughness also apply to dynamic loading and to steels in the hydrogen charged condition, with the lower toughness limit applied to older high-sulphur steels and the upper limit to newer low-sulphur steels.

6 Validation and comparison of proposed PIPIN approach with existing data

6.1 Identification of validation data sets

The approach proposed for PIPIN for hydrogen service is based on the estimation of fracture toughness from Charpy impact energy, followed by the application of a retention factor for the toughness in gaseous hydrogen environment at gas transmission and distribution pressures. To validate the approaches the following data are required:

- Pipeline grade
- Specified minimum Charpy impact requirement
- Actual Charpy impact energy for the pipe body
- Specified minimum yield stress
- Pipeline diameter
- Pipeline wall thickness

Many test programmes on the effect of hydrogen on pipeline steels focus solely on the effect on fracture toughness, without reference to the Charpy impact properties of the original pipeline steel. It is also useful to know the year of manufacture of the steel, to assess the effect of this on the accuracy of the predicted toughness. An extensive data set was published by DVGW (Deutscher Verein des Gas- und Wasserfaches e.v) in 2023 to support the construction or conversion of high-pressure gas pipelines in Germany (Steiner, Marewski, & Silcher, 2023). In this project, fracture toughness tests were performed on a representative cross-section of typical pipeline and valve steel grades used within Germany and other European countries, covering steels manufactured between the 1930s and 2020s.

Compact tension fracture toughness specimens were used and tested to ASTM E1820 in a servo-hydraulic testing machine with the sample located within the vessel under gaseous hydrogen conditions at 100 bar. This test arrangement is known as 'in-situ' and presents the most appropriate form of test as hydrogen is continually in contact with any newly exposed material at the crack tip during the test. The duration of any 'pre-soak' in hydrogen prior to testing and the displacement rate used in the tests were not however reported. The former is sometimes used to 'condition' the specimen as if it had already been in hydrogen service[5], while the latter must typically be at very slow rates of loading to

[5] Guidelines on fracture toughness testing of pipeline steels in hydrogen, published by the EPRG (European Pipeline Research Group) in 2024, suggest that hydrogen pre-soaking for fracture toughness testing of carbon steel pipeline materials is not necessary.

ensure the diffusion-controlled embrittlement process is active. Test temperature was not specified, but is most likely room temperature.

The dataset covered 35 materials, many with tests on pipe body, weld metal and HAZ within the same pipe. Some of these test materials are not applicable to the current context, and after review of grades, yield strengths and product forms, data for different steels were selected as being relevant to the current work, covering:

- 22 individual material data sets
- Year of manufacture 1930 to 2020
- 11 Pipeline grades X42 to X80
- 11 plate steels with equivalent API 5L strength grades B to X80
- Wall thickness range 8 to 37 mm
- Measured yield strength 294 to 584 MPa

For each grade the specified minimum yield stress, UTS and Charpy impact energy were given, as was the actual measured values of these properties. The measured fracture toughness in 100% hydrogen gas at 100 bar is given as K_{JIC} in MPa√m, determined from $J_{0.2\ mm}$[6]. All the necessary information is therefore included with which to assess the accuracy of the various methods covered in this report for predicting the fracture toughness of pipeline steels in 100% hydrogen at gas network pressures. However, the following are noted:

- The fracture toughness tests appear to have been carried out at room temperature, rather than the Charpy impact test temperature and design temperature for buried pipelines of 0°C[7]
- Loading rate for the tests is not given so it is not clear if the data represent the lower bound toughness that would be expected for slow rates of loading.
- The pressure is slightly higher than the typical gas pressures for much of the current UK transmission pipelines, where 75% operate at or below a maximum operating pressure (MOP) of 75 bar.

6.2 Results

The dataset of 22 steels from the DVGW study identified as relevant to pipeline grades was used to assess the accuracy and degree of conservatism of the proposed approach within PIPIN for estimating fracture toughness in hydrogen. The Charpy specification for each grade was used to estimate the fracture toughness in hydrogen at 0°C. The predicted value was then plotted against the value of fracture toughness measured in hydrogen from (Steiner, Marewski, & Silcher, 2023). The 1:1 line and lines representing ±20% were also plotted on the same axes. Data points lying above the 1:1 fit are conservative in that the

[6] The fracture toughness measured as J-integral at 0.2 mm of crack extension

[7] It is noted that fracture toughness testing in hydrogen at temperatures below ambient creates significant testing complications

predicted toughness is lower than the measured, while the opposite applies to those data points lying below the 1:1 line. The analysis was made for four cases:

- The proposed PIPIN method based on the Kiefner equation (equation 1) with minimum specification Charpy impact values and applying the proposed toughness retention factors in hydrogen (Figure 6)
- The BS7910 equation J.1 (equation 2) with minimum specification Charpy impact values, and applying the proposed toughness retention factors in hydrogen (Figure 7)
- The BS7910 equation J.1 (equation 2) with actual measured Charpy impact values, and applying the proposed toughness retention factors in hydrogen (Figure 8)
- The IGEM/TD1/H method (IGEM, 2021), based on minimum Charpy impact values (Figure 9)

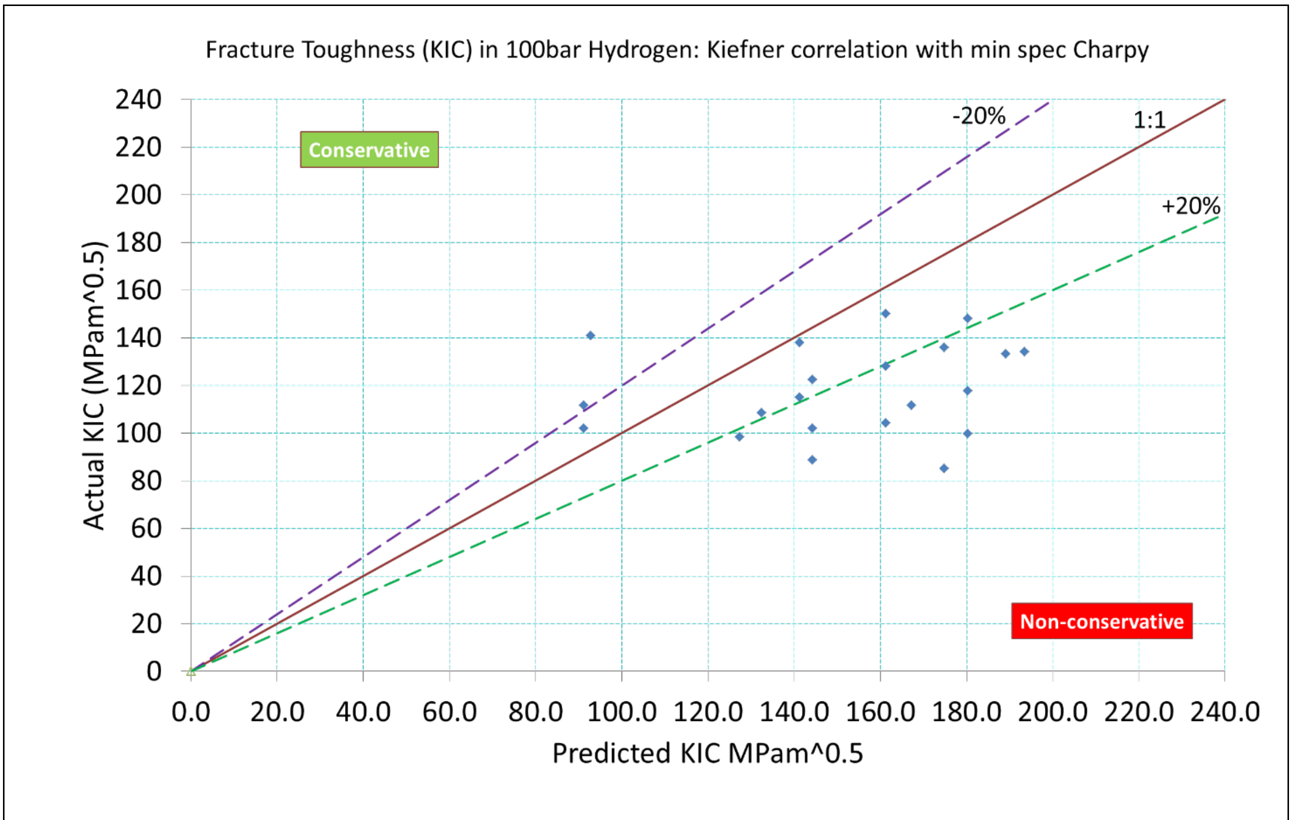

Figure 6: Comparison of predicted and actual fracture toughness in hydrogen using DVGW data and proposed PIPIN method

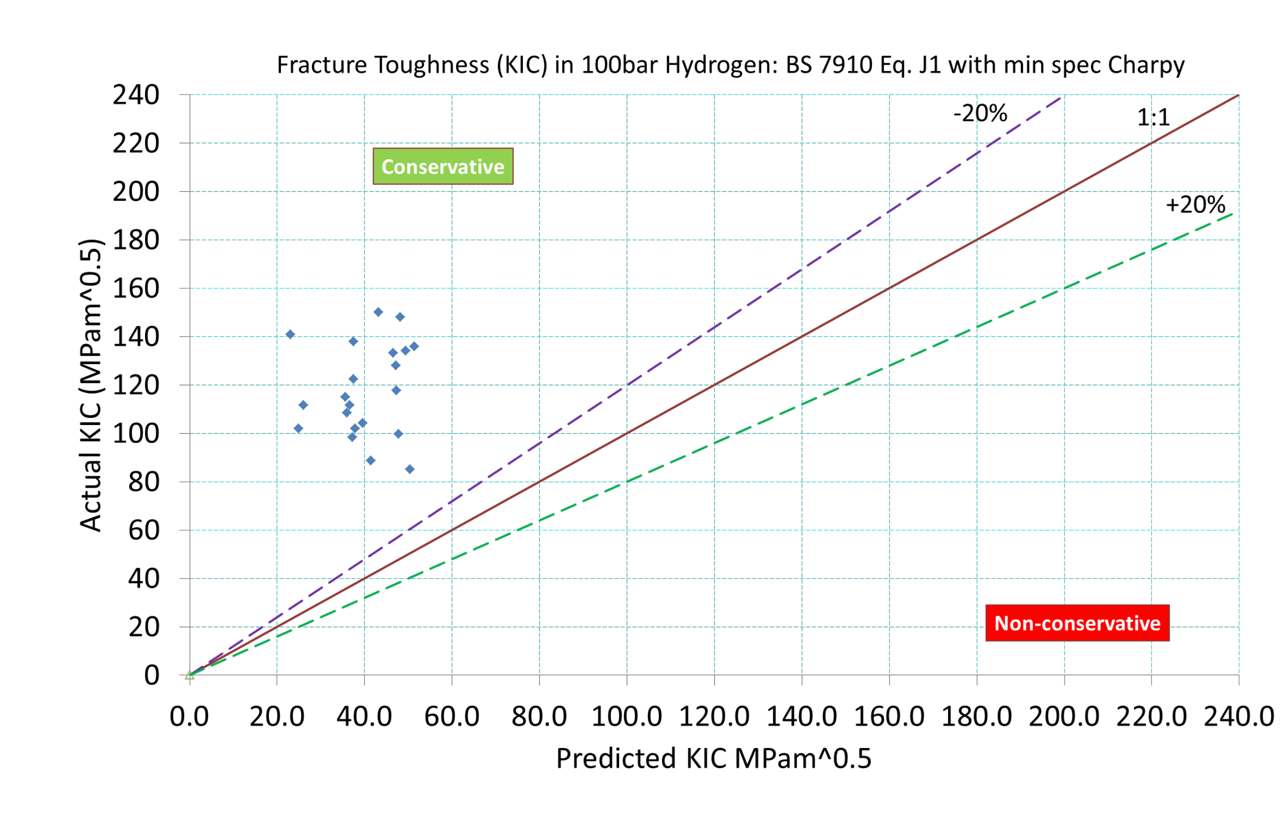

Figure 7: Comparison of predicted and actual fracture toughness in hydrogen using DVGW data and BS 7910 eq.J.1 with minimum specified Charpy impact energy

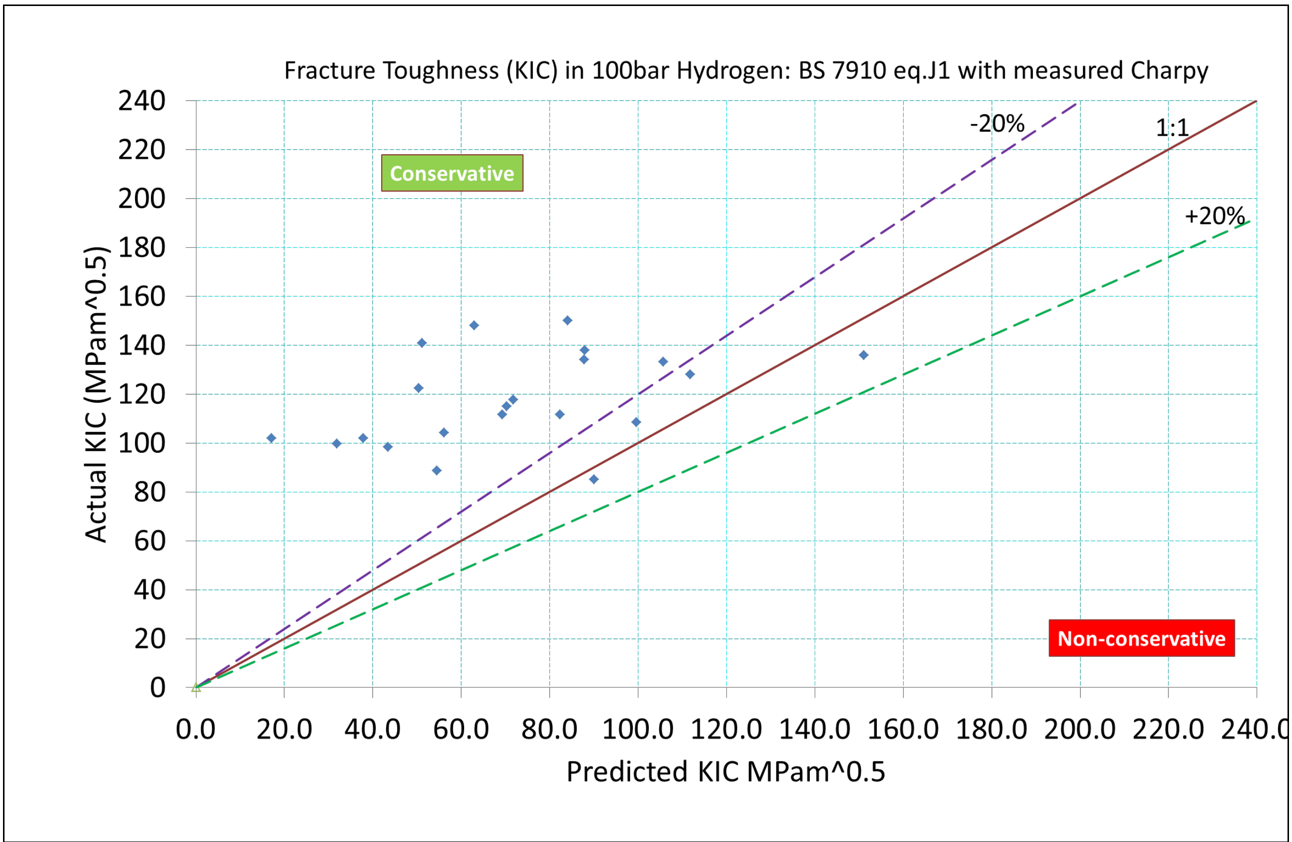

Figure 8: Comparison of predicted and actual fracture toughness in hydrogen using DVGW data and BS 7910 eq.J.1 with measured Charpy impact energy

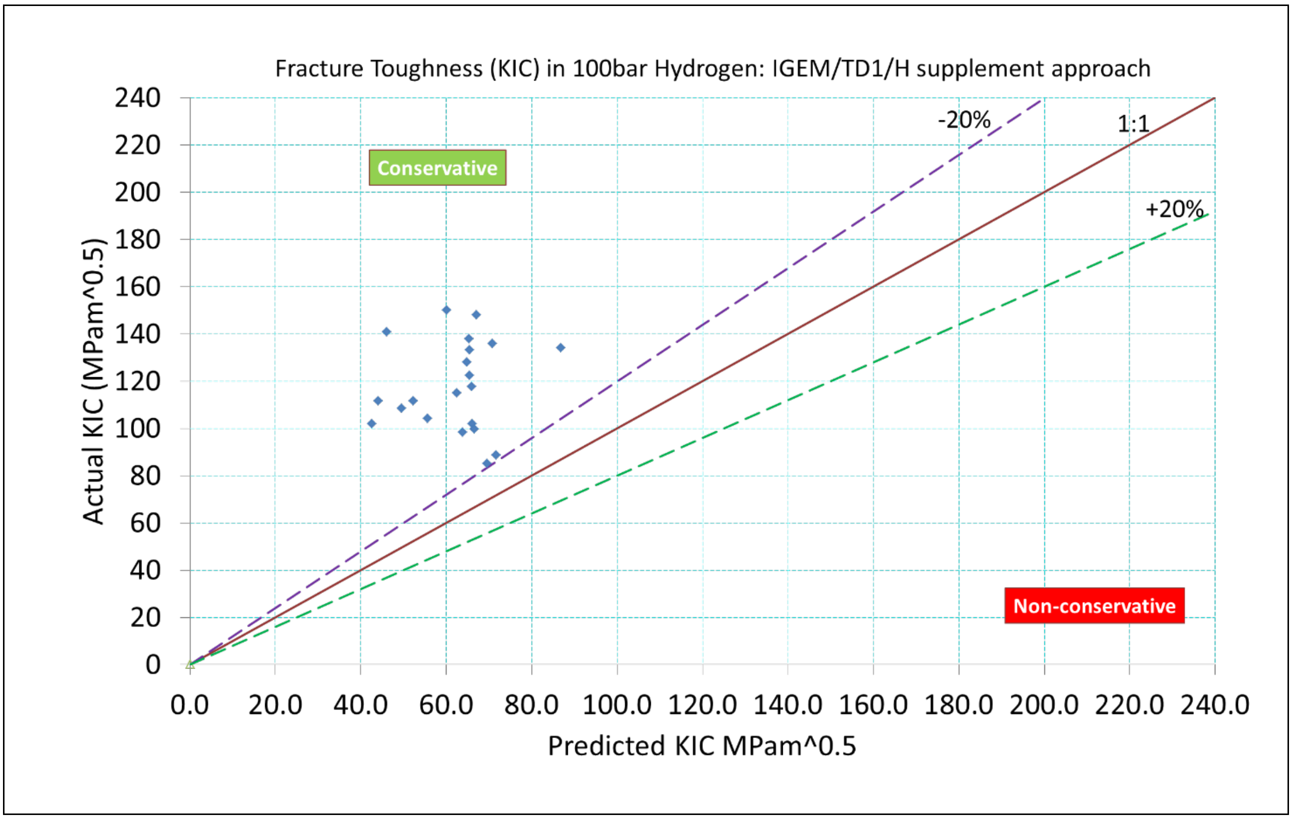

Figure 9: Comparison of predicted and actual fracture toughness in hydrogen using DVGW data and IGEM/TD/1 hydrogen supplement method

Using the Kiefner correlation (equation 1), 14% of data lie above the 1:1 line and 55% (12 of 22 data points) are below the +20% bounding line, Figure 6.

When using BS7910 eq.1 with minimum specified Charpy data, Figure 7, all data lie above the 1:1 line and are hence conservative. However, in this case the level of conservatism is extremely high with none of the 22 data points of predicted fracture toughness in hydrogen meeting the ASME B31.12 minimum requirement of 55 MPa√m. When using the actual measured Charpy value, this correlation gave a wider spread of predicted toughness with values up to 151 MPa√m, Figure 8, and only two points lying below the 1:1 line, hence still a very high level of conservatism.

Finally, using the IGEM/TD/1 hydrogen supplement method gives similar but slightly less conservative results than BS7910 equation J.1 using minimum Charpy energy. This is to be expected since both methods use the same correlation between Charpy impact energy and fracture toughness. However, in the IGEM approach the Charpy energy is first factored for hydrogen and then this value is used to calculate the fracture toughness. As the correlation is based on the square root of Charpy impact energy, the IGEM approach will always produce values which are a factor of 1.4× those determined when the factor is applied to the fracture toughness.

A comparison of some key observations from these four data analyses is given in Table 7.

Table 7: Comparison of fracture toughness prediction accuracy based on the four described approaches

	Expression and type of Charpy impact data used for correlation			
Case	(i)	(ii)	(iii)	(iv)
Description	Kiefner equation (Kiefner, Maxey, Eiber, & Duffy, 1973) (corrected) with minimum Charpy specification values	BS 7910 (BSI, 2019a) equation J.1 with minimum Charpy specification values	BS 7910 (BSI, 2019a) equation J1.1 with measured Charpy values	IGEM/TD1/H2 supplement (IGEM, 2021) with minimum Charpy specification values
Measure	**Fracture toughness (K_{IC}) in Hydrogen: Ratio of [predicted/actual]**			
Minimum	0.66	0.16	0.17	0.33
Maximum	2.06	0.59	1.11	0.82
Mean	1.29	0.34	0.59	0.53
Measure	**Percentage of data points**			
% over-predicted	86	0	9	0
% over-predicted by greater than 20% of K_{IC}	55	0	0	0

It is noted that the purpose of the PIPIN and MISHAP programs is to enable failure frequencies to be calculated for land use planning associated with current and future pipeline routes. It is not intended to provide a fitness-for-service assessment of a pipeline containing a known flaw. Hence, the high level of conservatism associated with the use of BS7910 correlations is not considered appropriate for the current application. In the case of the PIPIN model, actual Charpy test data per pipeline segment would not be known and minimum specified values for the grade must be used. Hence, the approach of using actual measured Charpy values, as reported on a material test certificate, is not practical.

The use of the Kiefner equation, together with the proposed factors for hydrogen operation, gives a mean fracture toughness across the 22 data sets of 1.29× the actual measured value. The mean overestimation of the fracture toughness in hydrogen when compared to the reference data set should be judged in the context of the intended use of PIPIN and several factors taken in combination. The Kiefner equation, together with the PIPIN method, has been shown historically to be suitable for LUP calculations for natural gas pipelines and hence is retained here for the hydrogen case. The method uses the minimum specified Charpy impact energy rather than actual values; the fracture toughness value determined is that for a high constraint specimen whereas many pipeline scenarios are low constraint (see section 3.1.1); and the Failure Assessment Diagram (FAD) method used to determine the significance of a postulated flaw generally produces conservative predictions. For the intended use of PIPIN, the proposed method for estimation of fracture toughness in hydrogen is considered appropriate.

7 Other Failure modes

7.1 Failure modes other than those arising from third party activity

Several other failure modes are covered within PIPIN beyond those associated with TPA described in Section 2.1, notably:

- **Ground movement**, including land movements due to earthquakes, heavy rains/floods and general subsidence of the surrounding earth, as well as operator error, and any other failures not captured under the other categories
- **Corrosion**, including both internal and external corrosion
- **Mechanical failures**, including construction failures

The potential effect of hydrogen on these failure modes is briefly discussed in the following sections. The failure frequencies referred to in each section are those from the UKOPA database as reported in (Chaplin & Howard, 2015), although other sources of data are used for some substances.

7.2 Ground movement and other

Ground movement and similar failures are taken as those due to external events that occur in the area surrounding a pipeline. They include natural events such as earthquakes, and landslides they may be either natural or caused by human interference. Events are likely to be location sensitive, for example where there is a fault line in the locality of the pipeline. The frequency of observed failure in natural gas pipelines is very low (Chaplin & Howard, 2015). Ground movement events tend to be displacement controlled rather than load controlled, such that permanent deformation of the pipeline often results. Common modes of failure (Choudhury & Chaudhuri, 2023) include shell buckling, cross-sectional ovalisation and tensile fracture.

High levels of ground movement that lead to permanent deformation of the pipeline will cause plastic strain[8] and associated work hardening of the steel. The ability to withstand high strains such as these depends on the steel possessing sufficient strength, toughness and ductility. Various studies on the mechanical properties of pipeline steels in hydrogen have shown the effect on strength to be minimal, while toughness is evaluated in detail elsewhere in this report.

[8] Plastic strains are defined as those beyond the elastic limit of the material. When strained beyond this limit in a tensile test the steel does not return to its original dimensions and retains an increment of permanent deformation

Ductility in pipeline steels is ensured by the inclusion of an elongation requirement in the tensile test for each grade, varying from 18 to 22% depending on grade. The uniform elongation, UEL, is the strain at UTS and is a more applicable parameter for quantifying strain performance. UEL is, however, not measured in a tensile test as part of pipeline material qualification but can be inferred from the yield strength. The effect of hydrogen on UEL has been little studied, although a significant reduction in total elongation has been measured for many pipeline steels in hydrogen gas. A reduction factor of 50% has been used for example calculations by Andrews et al. (Andrews, Gallon, & Huising, 2022).

In the current PIPIN model, the failure frequencies due to ground movement in natural gas pipelines are based on historical data. Laboratory-scale test data suggests that the elongation to failure, and therefore strain capacity, of pipeline steels in tensile tests in hydrogen is reduced. Furthermore, strain hardened regions of steel pipelines may have reduced toughness and have increased potential of hydrogen embrittlement. However, as only seven such ground movement events occurred in natural gas pipelines in the 22-year period leading up to the issue of RR1035 (Chaplin & Howard, 2015), the number of cases is limited. The current PIPIN model does not consider the mechanical properties of the pipeline steel for determining the failure frequency due to ground movement, and hence no modifications for a change to hydrogen service are practicable. However, the potential for incorporating this at a later stage should be considered.

Other failures that are captured in this category include lightning strike. It is not expected that the presence of hydrogen will increase the likelihood of failure from this cause.

7.3 External corrosion

Corrosion failures in pipelines are generally a function of the commodity transported, the wall thickness of the pipeline and the external conditions. Internal corrosion is a function of the commodity being transported, while external corrosion is independent of this. Internal corrosion in natural gas pipelines in the UK is rare in normal operations due to the low water content of natural gas[9]. External corrosion is dependent on the type of soil in which the pipeline is located, the water levels, the pipeline material and age, presence of physical corrosion protection such as coatings and the use of active corrosion prevention methods such as cathodic protection. The latter may be achieved through either impressed current or the use of sacrificial anodes. Cathodic over-protection from poorly controlled impressed current systems can lead to the generation of hydrogen, but this is independent of the gas being conveyed.

There were 19 failures attributed to corrosion in the 22-year period leading up to the issue of RR1035 (Chaplin & Howard, 2015), 14 external, one internal and four due to stress corrosion cracking (SCC). Four cases were subsequently discounted due to zero depth of cover, leaving 15 in total.

[9] In the UK the permissible water content of natural gas depends on the pressure tier and is conventionally defined by the dew point. Conversion of these dew points to a typical water content limit for transmission and distribution pressures gives typical maxima in the range 50 to 100 ppm.

An increase in the rate of metal loss due to external corrosion is not expected due to the presence of hydrogen within the pipe. Any external volumetric corrosion defects may affect the remaining strength of the pipe. Where these regions are of sufficiently sharp geometry to be considered as a crack-like defect, the reduced toughness of the pipe material in hydrogen may increase the failure frequency from these. Where the corrosion geometry is not crack or notch-like, the remaining strength will be controlled by the tensile properties of the pipeline steel, which are little affected by the presence of hydrogen. Hydrogen was noted to have a minor effect on corrosion-related failure probability in a recent study on a causal model incorporating multiple failure causes of transmission pipelines (Yang, Schell, Rayasam, & Groth, 2025).

The presence of dry hydrogen gas within the pipe would not be expected to lead to stress corrosion cracking. However, any pre-existing SCC may become more significant in the presence of hydrogen due to potentially reduced toughness of the pipe material.

Hence, while the significance of pre-existing corrosion defects may be affected by the change of gas to hydrogen, the net rate of corrosion and hence frequency of occurrences is not expected to be affected by hydrogen.

7.4 Mechanical failures

This category is a function of the material and construction detail of the pipeline or its design and is generally independent of both the commodity being transported and the locality of the pipeline. There were 26 events attributed to mechanical damage within the UKOPA dataset in the 22-year period leading up to the issue of RR1035 (Chaplin & Howard, 2015). This data set showed a very high dependency on wall thickness, with 19 of the events occurring in pipe of wall thickness <5 mm and all 23 of the events occurring in diameters below 273 mm. The mechanism has a strong weighting towards thin–walled, small–diameter, pipes. The failure frequency for this mode is not expected to be affected by hydrogen.

7.5 Other considerations

The potential for arresting a running ductile fracture in a hydrogen pipeline has been evaluated by Cosham (Cosham, 2024). The study concluded that the Charpy impact energy required to arrest such a fracture in a pipeline transporting hydrogen is less than that in an otherwise identical pipeline transporting natural gas due to the higher speed of the decompression wave in hydrogen.

The mechanism of fatigue crack growth due to cyclic loading is not included in PIPIN. Gas pressure cycling due to temporary pressure increase for gas storage (line-packing) is a potential source of cyclic hoop stress in pipelines. IGEM TD/1 and TD/1 supplement 2 cover high pressure pipelines for natural gas and hydrogen respectively, and each contains recommended approaches for fatigue assessment where this is deemed necessary. The fatigue crack growth rates for pipeline steels are higher in hydrogen than in natural gas.

8 Effects of proposed changes

Whilst the changes to PIPIN detailed in the previous sections have been primarily to enable the model to calculate failure rates for hydrogen pipelines, some changes have been made that will affect all pipelines. A set of 584 methane pipelines has therefore been run using the current version of PIPIN (V3.04) and compared with the proposed new version of PIPIN (V3.1) (see Appendix 2, Section 12.1 for the pipeline details). This will demonstrate how big an effect the changes have on existing pipeline failure rates.

In addition, a set of non-natural gas pipelines has been run through both versions of PIPIN to ascertain the effects on the failure rates of using to the new version. The pipeline details are in Appendix 2, Section 12.2, noting that this does not include hydrogen.

The results of the analysis for the methane pipelines are shown in Section 0, whilst those for the non-natural gas pipelines are shown in Section 8.2. The results from the new version of PIPIN will form a baseline to compare the equivalent hydrogen pipelines against. This comparison is shown in Section 0.

The failure rates are used within a pipeline risk assessment code, MISHAP (Chaplin, 2015), which calculates the risk from, and ultimately the Land Use Planning (LUP) zones associated with major accident hazard pipelines. MISHAP is not currently capable of calculating the risks from hydrogen pipelines, but has been run for the methane and non-natural gas scenarios to ascertain the effect of the changes in failure rate on the final LUP zones. These are shown in Section 8.4, although it should be noted that those for the non-natural gas scenarios are indicative only. A more complex method is used to generate LUP zones for these pipelines that involves running additional models, including rain out, pool formation and pool evaporation. The more complicated process has not been undertaken for this work.

8.1 Methane failure rates

This section compares the methane failure rates using the current version of PIPIN (3.04) and the proposed version of PIPIN (3.1). Summary statistics have been derived showing the maximum and minimum differences, both in absolute and percentage terms, together with the standard deviation and the mean. These are shown in Table 8, where the differences are the new results – the old PIPIN results and the percentage differences are the difference divided by the old PIPIN results. The full results can be found in Appendix 3, Section 13.1 for PIPIN 3.04 and in Appendix 3, Section 13.2 for PIPIN 3.1. The full set of comparisons between PIPIN 3.1 and PIPIN 3.04 for the methane pipelines can be found in Appendix 3, Section 13.3.

Table 8 Summary statistics for the PIPIN comparison of methane failure rates

Statistic	Failure rate difference (per m per yr)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
Max	0	0	0	0	0.0	0.0	0.0	0.0
Min	-9.0E-09	-3.0E-10	-1.3E-09	-1.4E-08	-23.3	-16.1	-9.5	-12.4
Standard deviation	1.8E-09	6.5E-11	3.0E-10	3.1E-09	N/A	N/A	N/A	N/A
Mean	-1.9E-09	-8.0E-11	-3.7E-10	-4.2E-09	-6.4	-3.9	-2.9	-2.6

From Table 8 it can be seen, from the zero values in the max change row, that none of the 584 pipelines see an increase in failure rates when the changes to PIPIN have been applied. The largest difference is a 23% reduction in the rupture failure rate, with smaller differences seen for the other hole sizes. The mean differences across all the pipelines equate to approximately a 3% reduction for small holes and pin holes, 4% for large holes and 6.5% for ruptures. The standard deviations are all low, meaning that the majority of the pipelines have differences that are not too dissimilar to the mean values. On average, the differences in the methane pipeline failure rates between the two versions of PIPIN are small.

Further investigation has been undertaken to ascertain the number of pipelines that see a reduction of at least 10% in any of the hole sizes. This reveals that there are 17 pipelines where this occurs for ruptures, 4 for large holes, none for small holes and 3 for pin holes.

8.2 Non-natural gas failure rates

This section compares the failure rates for a selection of non-natural gas pipelines (note that hydrogen is not included in the test set of pipelines), using the current version of PIPIN (3.04) and the proposed version of PIPIN (3.1). Summary statistics have been derived showing the maximum and minimum differences, both in absolute and percentage terms, together with the standard deviation and the mean. These are shown in Table 9, where the differences are the new results – the old PIPIN results and the percentage differences are the difference divided by the old PIPIN results. The full results can be found in Appendix 4, Section 14.1 for PIPIN 3.04 and in Appendix 4, Section 14.2 for PIPIN 3.1. The full set of comparisons between PIPIN 3.1 and PIPIN 3.04 for the non-natural gas pipelines can be found in Appendix 4, Section 14.3.

Table 9 Summary statistics for the PIPIN comparison of non-natural gas failure rates

Statistic	Failure rate difference (per m per yr)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
Max	0	0	0	0	0.0	0.0	0.0	0.0
Min	-2.7E-09	-2.0E-10	-8.0E-10	-8.0E-09	0.0	0.0	-6.0	-3.7
Standard deviation	6.5E-10	6.0E-11	2.4E-10	2.3E-09	N/A	N/A	N/A	N/A
Mean	-1.0E-09	-5.4E-11	-2.4E-10	-2.6E-09	0.0	0.0	-4.5	-1.7

From Table 9 it can be seen that there are no increases and no significant decreases in the failure rates for non-natural gas pipelines, with the largest change corresponding to a 6% decrease. This implies that the changes to PIPIN have had a negligible impact on the results for non-natural gas pipelines.

8.3 Hydrogen failure rates

PIPIN V3.1 has been run for 584 pipelines containing hydrogen, and compared to the methane results discussed previously (Section 8.1). The maximum, minimum and mean absolute and percentage differences are shown in Table 10, together with the standard deviation. The differences are calculated as hydrogen – methane and the percentage differences are (hydrogen – methane) / methane. The full results are in Appendix 5, Sections 15.1 and 15.2.

Table 10 Summary statistics for the PIPIN comparison of hydrogen and methane failure rates

Statistic	Failure rate difference (per m per yr)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
Max	1.3E-07	4.1E-09	1.9E-08	2.0E-07	364.1	180.3	118.5	148.5
Min	2.0E-11	-5.0E-11	-2.0E-10	-1.0E-09	0.8	-2.2	-1.7	-0.2
Standard deviation	3.2E-08	8.7E-10	4.1E-09	4.4E-08	N/A	N/A	N/A	N/A
Mean	3.8E-08	1.1E-09	5.3E-09	6.0E-08	151.6	62.5	45.2	40.9

From Table 10 it can be seen that there are some significant increases in the failure rates for hydrogen pipelines. The mean increase is over 150% for ruptures, with smaller increases for the other hole sizes.

The increases are to be expected, given the factors that have been applied to some aspects of the calculations for hydrogen, as detailed in the preceding sections.

There is one pipeline which sees a decrease in the pin, small and large hole failure rates. This would appear to be incorrect, given the factors that have been applied, but can be explained as follows.

PIPIN contains three fracture mechanics models; one for gouges, one for dent-gouges and one for ruptures. The gouge and rupture models are run twice, once with gouge data and once with dent-gouge data, making five models in total. The modifications to PIPIN described in the preceding sections apply to the dent-gouge and rupture models only; the gouge model is unchanged.

In general, the failure probabilities associated with the dent-gouge model and the rupture models are orders of magnitude larger than those for the gouge model. For hydrogen, this means that the failure probabilities, and hence the final failure rates, increase due to the factors that are applied. For pipelines with smaller wall thicknesses, however, the results of the gouge model start to become more important. For very small wall thicknesses, the gouge model results are of a similar order of magnitude to dent-gouges. The effect of the changes to the rupture model is that, for hydrogen, more of the gouges progress to ruptures. This means that, for hydrogen, there is a lower probability of a pin hole, small hole or large hole as a result of a gouge than there would be for methane. The pipeline for which the failure rate decreases with hydrogen has a wall thickness of just 4.4 mm but a pressure of 70 barg. In this case, the gouge model makes an approximately equal contribution to the overall failure rate as the dent-gouge model. The increased proportion of ruptures in the hydrogen scenario ultimately then leads to reduced failure rates for the other hole sizes when compared to methane.

8.4 Comparison of MISHAP LUP zones calculated when using PIPIN V3.04 and PIPIN V3.1

The failure rates calculated by PIPIN are used within MISHAP, which calculates Land Use Planning (LUP) zones around Major Accident Hazard (MAH) pipelines. MISHAP cannot currently run with hydrogen, but it is necessary to gain an overview of what effect the proposed changes to PIPIN will have on the existing zones. MISHAP has therefore been run for the 584 methane pipelines using the failure rates from both PIPIN V3.04 and V3.1 and for the non-natural gas pipelines. It should be noted that the LUP zones for the non-natural gas pipelines are indicative only as a slightly more complex methodology is generally used that entails running models outside of MISHAP. In addition, an earlier version of MISHAP was used that did not incorporate more recent changes to some of the consequence models, which means that the results for all substances can only be used to provide an indication of the level of changes that will be seen through the modifications to PIPIN.

8.4.1 Methane pipelines

Summary results for the methane pipelines are shown in Table 11, where the differences are calculated as new – old and the percentage differences are (new – old) / old. In this case “new” refers to the results obtained when the failure rates have been calculated using PIPIN V3.1 and “old” are the results from using PIPIN V3.04 for the failure rates. The full set of results for the methane pipelines can be found in Appendix 6, Section 16.1.

Table 11 Summary statistics for the differences in LUP zones using the current and proposed versions of PIPIN

Statistic	Methane LUP Zone Difference (m)			Methane LUP Zone Difference (%)		
	IZ	MZ	OZ	IZ	MZ	OZ
Max	0	0	0	0.0	0.0	0.0
Min	0	-80	-20	0.0	-65.1	-40.0
Standard Deviation	0.0	9.8	2.7	N/A	N/A	N/A
Mean	0.0	-2.8	-1.5	0.0	-3.8	-2.2

From Table 11 it can be seen that there are no changes in the inner zone when using the revised version of PIPIN. This is because the inner zone for methane pipelines is generally based on the building proximity distance (BPD), which is not calculated within PIPIN. On average, the changes to the other two zones are small but there are some pipelines which see a large decrease in zone size. No pipelines see an increase in zone size when using the proposed version of PIPIN.

To gain a better understanding of the differences, the number of pipelines with a 25% or greater decrease in zone size has been calculated. This has identified that there are 29 pipelines with at least a 25% decrease in the size of the middle zone, using the new version of PIPIN, and four in the outer zone.

The number of pipelines with a decrease of 20 m or more in the zone size has also been calculated. In this case there are 21 pipelines with a decrease of at least 20 m in the middle zone and one in the outer zone.

These additional calculations indicate that, whilst there are some pipelines that see a much more significant decrease in zone size through the use of the revised version of PIPIN, they represent only a relatively small proportion of the pipelines modelled.

8.4.2 Non-natural gas pipelines

Summary results for the non-natural gas pipelines are shown in Table 12, where the differences are calculated as new – old and the percentage differences are (new – old) /

old. In this case “new” refers to the results obtained when the failure rates have been calculated using PIPIN V3.1 and “old” are the results from using PIPIN V3.04 for the failure rates. The full set of results for the non-natural gas pipelines can be found in Appendix 16, Section 16.2.

Table 12 Summary statistics for the differences in LUP zones using the current and proposed versions of PIPIN

Statistic	Non-NG LUP Zone Difference (m)			Non-NG LUP Zone Difference (%)		
	IZ	MZ	OZ	IZ	MZ	OZ
Max	0.0	0.0	0.0	0.0	0.0	0.0
Min	-5.0	-110.0	-20.0	-3.8	-12.9	-5.3
Standard Deviation	1.2	25.7	4.9	N/A	N/A	N/A
Mean	-0.3	-7.2	-2.1	-0.2	-1.7	-0.7

From Table 12 it can be seen that there is a reduction of up to 5 m in the inner zone when using version 3.1 of PIPIN. This occurs for one ethylene pipeline, where the inner zone is not based on the Minimum Distance to Occupied Buildings (MDOB). The inner zone for the other pipelines is based on the MDOB, which is unaffected by the change to PIPIN.

There is one pipeline that sees a large decrease (110 m) in the middle zone and another that sees a decrease of 20 m in the outer zone. The remainder of the pipelines either see no change or small decreases of up to 5 m. The larger decreases can be explained by examining the risk versus distance curves for these scenarios. In these cases, the region of the curve that corresponds to the risk under consideration is very flat. A very small change in the risk therefore leads to a very large change in the distance.

9 Conclusions

The Health and Safety Executive (HSE) use a computer code, PIPIN (PIPeline INtegrity), to determine failure frequencies of major accident hazard pipelines. PIPIN calculates the failure rates of pipelines for various modes of failure, which are then used in in other tools, such as MISHAP (Model for the estimation of Individual and Societal risk from HAzards of Pipelines). PIPIN contains two approaches for the determination of failure rates. The first is based on operational experience data, the second is a predictive model that uses structural reliability techniques to predict the failure frequency due to third party activity (TPA). The model for TPA requires the fracture toughness of the pipeline steel as an input.

The current report covers the potential effects of hydrogen on the fracture toughness, and other mechanical properties, of pipeline steels and makes proposals for the changes to the method to account for this.

Experimental test data for tensile properties of pipeline steels in hydrogen environments show that yield strength and ultimate tensile strength are little affected by hydrogen. Consequently, the material properties inputs of the existing PIPIN fracture mechanics based models, which use these parameters, do not require modification for application to hydrogen pipelines.

The required inputs for the dent-gouge and rupture models in PIPIN include fracture toughness of the steel pipeline. This is known to be adversely affected by the presence of hydrogen and must therefore be modified for the PIPIN approach to be applicable to hydrogen pipelines.

In PIPIN, only the pipe grade, diameter and wall thickness are known. Each pipe grade to BS EN or API standards has a Charpy impact test requirement. Fracture toughness can be estimated from Charpy impact energy using published correlations, although there are a large number of factors that affect the accuracy of such correlations. The correlation between Charpy impact energy and fracture toughness currently used within the PIPIN model is that of Kiefner et al. (ASTM STP 536, 1973). This correlation is suitable for the application represented by PIPIN, that of land use planning scenarios rather than fitness-for-service assessment of an existing pipe, although it does not generate conservative estimates in all cases. Alternative correlations from BS7910 proved extremely conservative for this purpose, and significantly underestimated the fracture toughness.

Since the Charpy impact energy is an impact test, the diffusion controlled effects of hydrogen embrittlement are not active in such a test. In the context of PIPIN, the fracture toughness in an ambient environment must first be determined from the Charpy impact energy, followed by the application of a factor to this value to allow for the effects of hydrogen.

The proposed approach for determination of the value of fracture toughness in hydrogen is based on use of the Kiefner correlation currently used in PIPIN to estimate fracture toughness, which is then reduced by a specified factor to account for the effect of hydrogen. The toughness retention factors for hydrogen have been determined based on test data in the literature and vary from 0.35 to 0.50. The factor varies depending on pipe strength grade, while installation decade is also inherently included based on the decades of introduction of certain grades.

Checks against a published data set on the fracture toughness of 22 pipeline and plate steels in 100 bar hydrogen showed that the mean predicted toughness using the developed method was 1.29 times the actual measured toughness. 55% of predictions were higher than the measured value +20%.

Several other failure modes are covered within PIPIN beyond those associated with TPA; ground movement, including land movements due to earthquakes, heavy rains/floods and general subsidence of the surrounding earth; corrosion, including both internal and external, and; mechanical failures, including construction failures. The potential effect of hydrogen on these failure modes is briefly discussed. However, as none of the mechanical properties of pipeline steels that are adversely affected by hydrogen form inputs for these analyses within PIPIN, a change to the calculated failure frequencies for these failure modes would not be expected when using this code. Models for pipeline failure due to strain from ground movement exist, and if such a model was incorporated into PIPIN, a correction for the strain capacity of the pipeline steel in hydrogen would be appropriate but this is not currently proposed.

The analysis presented in this report applies to estimations of failure frequencies for LUP purposes, where the condition of the pipe is unknown. The approach is not applicable to fitness-for-service determination for existing pipes containing known or postulated damage. The level of conservatism in the proposed approach is therefore considered acceptable and reflects this difference.

The effects of the changes to the model have been assessed for a set of 584 hydrogen and natural gas pipelines, together with a set of non-natural gas pipelines. As expected, the comparison of hydrogen failure rates to natural gas shows that the failure rates are generally higher for hydrogen. The effects of the changes on the non-natural gas pipelines is negligible. For natural gas, some larger changes are observed but, in general, the differences are minor.

The LUP zones have been calculated for the natural gas and non-natural gas pipelines to determine what effect the changes in the failure rates will have on the LUP zones. It is not possible, currently, to calculate the zones for hydrogen. The zones using the revised failure rates have been compared to those using the existing failure rates. In general, small changes are observed, with many pipelines showing no change at all. There are a few natural gas pipelines which observe a larger change in the middle and outer zones. In all the natural gas cases, the middle and outer zones decrease in size with no change in the inner zones.

Similarly, the majority of the changes to the zones for the non-natural gas pipelines are 5 m or less. There are a couple of exceptions, which are due to the risk versus distance curve being very flat in the area of interest, meaning that a very small change in risk leads to a very large change in distance.

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11 Appendix 1 Validation data set

Grade	Year	API equivalent strength grade	Wall Thick, t (mm)	SMYS (MPa)	Actual YS (MPa)	CV min/ spec/ J	Cv actual (J)	Cv equiv t= 10mm (J)	Cv Test Temp Deg C	Measured K_{IC} pipe body in 100bar H_2 ($K_{J0.2mm}$)	K_{IC} Air (Kiefner equation) (MPam^0.5)	Hydrogen toughness retention factor	Predicted toughness (K_{IC}) in hydrogen from Kiefner (MPam^0.5)	Ratio K_{IC} in hydrogen (predicted/ measured)
API 5L grade A	1962	Grade A	13	207	297	20	17	17	0	109.5	228.0	0.4	91.2	0.83
St35	1930	Grade A	10	235	294	20	10	10	0	101.9	228.0	0.4	91.2	0.90
St35	1937	Grade A	7.75	235	347	20	94	125	0	111.6	228.0	0.4	91.2	0.82
St35	1955	Grade A	8	225	316	39	39	52	0	98.4	318.4	0.4	127.4	1.29
API 5L X42	1961	X42	9	289	297	50	63	84	0	88.6	360.6	0.4	144.2	1.63
St43.7	1972	X42	14.2	294	318	50	50	50	0	101.9	360.6	0.4	144.2	1.42
L360 NB batch 2	2010	X52	12.5	360	449	40	145	145	0	150	322.5	0.5	161.3	1.08
X46	1964	X46	8.8	320	413	47	107	143	0	85	349.6	0.5	174.8	2.06
StE360.7	1996	X52	8	360	451	47	281	375	0	135.9	349.6	0.5	174.8	1.29
StE480.7	1997	X70	13.4	480	508	48	253	253	0	138	353.3	0.4	141.3	1.02
L360 NB	2013	X52	8	360	423	40	156	208	0	128	322.5	0.5	161.3	1.26
St53.7	1972	X52	14.37	363	381	50	113	113	0	117.7	360.6	0.5	180.3	1.53
X56	1990	X56	13.6	392	486	50	23	23	0	99.6	360.6	0.5	180.3	1.81
St60.7	1973	X60	13	412	517	50	84	84	0	148.1	360.6	0.5	180.3	1.22
P460 NH	2017	X65	20	445	448	40	80	80	0	104.1	322.5	0.5	161.3	1.55
X70	1974	X70	15	491	517	50	89	89	0	122.5	360.6	0.4	144.2	1.18
L485	2017	X70	16.8	485	527	90	280	280	0	134.2	483.8	0.4	193.5	1.44
L485 ME	2017	X70	17.5	485	520	48	183	183	0	115	353.3	0.4	141.3	1.23
X80	1992	X80	18.3	550	584	27	130	130	0	140.9	265.0	0.35	92.7	0.66
L415	2020	X60	11.1	415	468	27	192	192	0	108.5	265.0	0.5	132.5	1.22
P355 NL1	2013	X52	37	345	365	43	224	224	0	111.6	334.4	0.5	167.2	1.50
TStE 355N	2002	X52	20	355	434	55	281	281	0	133.3	378.2	0.5	189.1	1.42
													Maximum	**2.06**
													Minimum	**0.66**
													Mean	**1.29**

Key	
	Estimated/ assumed
	Sub-size Charpy specimen
	Measured K_{IC} in hydrogen
	K_{IC} in air from min spec Charpy
	K_{IC} in H_2 from min spec Charpy

12 Appendix 2 Pipeline datasets

This section details the set of pipelines used in the methane and non-natural gas tests.

12.1 Methane pipelines

Table 13 Parameters of the 584 pipelines that form the test set

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
1	1219.2	19.1	API5L	X65	75	1100	Rural	No	No
2	1219.2	15.9	API5L	X80	75	1100	Rural	No	No
3	1219.2	15.1	API5L	X80	75	1100	Rural	No	No
4	1219.2	14.3	API5L	X80	75	1100	Rural	No	No
5	1219.2	15.9	API5L	X65	70	1100	Rural	No	No
6	1219.2	15.1	API5L	X80	70	1100	Rural	No	No
7	1219.2	14.3	API5L	X65	70	1100	Rural	No	No
8	1219.2	12.7	API5L	X60	48.2	1100	Rural	No	No
9	1219.2	17.5	API5L	X65	36.5	1100	Suburban	No	No
10	1066.8	14.3	API5L	X60	80	1100	Rural	No	No
11	1066.8	14.3	API5L	X60	75	1100	Rural	No	No
12	1066.8	14.3	API5L	X60	70	1100	Rural	No	No
13	1066.8	14.3	API5L	X65	70	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
14	1066.8	19.1	API5L	X65	38	1100	Suburban	No	No
15	1066.8	14.3	API5L	X60	32	1100	Suburban	No	No
16	1066.8	12.7	API5L	X56	26.2	1100	Suburban	No	No
17	914.4	12.7	API5L	X60	85	1100	Rural	No	No
18	914.4	15.9	API5L	X60	75	900	Rural	No	No
19	914.4	12.7	API5L	X60	75	1100	Rural	No	No
20	914.4	12.7	API5L	X60	75	1000	Rural	No	No
21	914.4	12.7	API5L	X60	75	900	Rural	No	No
22	914.4	12.7	API5L	X65	75	1100	Rural	No	No
23	914.4	15.9	API5L	X56	70	900	Rural	No	No
24	914.4	15.9	API5L	X60	70	1100	Rural	No	No
25	914.4	15.9	API5L	X60	70	1000	Rural	No	No
26	914.4	15.9	API5L	X60	70	900	Rural	No	No
27	914.4	14.3	API5L	X60	70	1100	Rural	No	No
28	914.4	12.7	API5L	X60	70	1100	Rural	No	No
29	914.4	12.7	API5L	X60	70	1100	Rural	No	No
30	914.4	12.7	API5L	X60	70	900	Rural	No	No
31	914.4	12.7	API5L	X60	70	900	Rural	No	No
32	914.4	12.7	API5L	X60	70	900	Rural	No	No
33	914.4	12.7	API5L	X60	70	900	Rural	No	No
34	914.4	15.9	API5L	X65	55	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
35	914.4	12.7	API5L	X60	44.8	1100	Rural	No	No
36	914.4	12.7	API5L	X60	38	1100	Rural	No	No
37	914.4	12.7	API5L	X60	38	1000	Rural	No	No
38	914.4	12.7	API5L	X60	32	1100	Suburban	No	No
39	914.4	8.7	API5L	X52	27.5	1100	Rural	No	No
40	914.4	12.7	API5L	X60	26.2	1100	Suburban	No	No
41	762	12.7	API5L	X60	75	1100	Rural	No	No
42	762	12.7	API5L	X60	75	1000	Rural	No	No
43	762	11.9	API5L	X52	75	1100	Rural	No	No
44	762	11.9	API5L	X65	75	1100	Rural	No	No
45	762	15.9	API5L	X52	70	1100	Rural	No	No
46	762	12.7	API5L	X60	70	1100	Rural	No	No
47	762	12.7	API5L	X60	70	900	Rural	No	No
48	762	12.7	API5L	X60	70	900	Rural	No	No
49	762	11.9	API5L	X52	70	1100	Rural	No	No
50	762	11.9	API5L	X52	70	1000	Rural	No	No
51	762	11.9	API5L	X52	70	900	Rural	No	No
52	762	11.9	API5L	X60	70	1100	Rural	No	No
53	762	15.9	API5L	X52	42.7	1100	Suburban	No	No
54	762	15.9	API5L	X52	39.2	1100	Suburban	No	No
55	762	12.7	API5L	X52	39.2	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
56	762	11.9	API5L	X52	39.2	1100	Rural	No	No
57	762	15.9	API5L	X52	38	1100	Suburban	No	No
58	762	15.9	API5L	X52	38	1000	Suburban	No	No
59	762	15.9	API5L	X52	38	900	Suburban	No	No
60	762	12.7	API5L	X60	38	1100	Suburban	No	No
61	762	12.7	API5L	X60	38	1000	Suburban	No	No
62	762	12.7	API5L	X60	38	1000	Suburban	No	No
63	762	11.9	API5L	X52	38	1100	Rural	No	No
64	762	11.9	API5L	X52	38	1000	Rural	No	No
65	762	14.3	API5L	X52	37.2	1100	Suburban	No	No
66	762	15.9	API5L	X60	33.1	1100	Suburban	No	No
67	762	12.7	API5L	X56	33.1	1100	Suburban	No	No
68	762	12.7	API5L	X56	33.1	900	Suburban	No	No
69	762	12.7	API5L	X60	33.1	1100	Suburban	No	No
70	762	12.7	API5L	X60	32	1100	Suburban	No	No
71	762	11.9	API5L	X52	32	1100	Suburban	No	No
72	762	10.7	API5L	B	19	1100	Suburban	No	No
73	762	9.5	API5L	X52	19	1100	Suburban	No	No
74	762	11.9	API5L	X52	12.7	1100	Suburban	No	No
75	609.6	11.9	API5L	X52	75	900	Rural	No	No
76	609.6	9.5	API5L	X52	75	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
77	609.6	14.3	API5L	X52	70	1100	Rural	No	No
78	609.6	11.9	API5L	X52	70	900	Rural	No	No
79	609.6	11.9	API5L	X52	70	1100	Rural	No	No
80	609.6	11.9	API5L	X52	70	1000	Rural	No	No
81	609.6	11.9	API5L	X52	70	900	Rural	No	No
82	609.6	9.5	API5L	X52	70	1100	Rural	No	No
83	609.6	9.5	API5L	X52	70	900	Rural	No	No
84	609.6	9.5	API5L	X52	69	1100	Rural	No	No
85	609.6	9.5	API5L	X52	68.9	1100	Rural	No	No
86	609.6	9.5	API5L	X52	50	1100	Rural	No	No
87	609.6	14.3	API5L	X52	48.3	1100	Suburban	No	No
88	609.6	14.3	API5L	X52	48.3	1000	Suburban	No	No
89	609.6	12.7	API5L	X52	48.3	1000	Rural	No	No
90	609.6	9.5	API5L	X52	48.3	1100	Rural	No	No
91	609.6	11.9	API5L	X60	46	1100	Suburban	No	No
92	609.6	12.7	API5L	X52	42	1100	Suburban	No	No
93	609.6	11.9	API5L	X46	42	1100	Rural	No	No
94	609.6	11.9	API5L	X52	42	1100	Suburban	No	No
95	609.6	11.9	API5L	X52	42	1000	Suburban	No	No
96	609.6	11.9	API5L	X52	42	1000	Suburban	No	No
97	609.6	9.5	API5L	X52	42	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
98	609.6	11.9	API5L	X52	40	1100	Suburban	No	No
99	609.6	9.5	API5L	X52	39.9	1100	Rural	No	No
100	609.6	11.9	API5L	X52	39.5	1000	Suburban	No	No
101	609.6	11.9	API5L	X52	38.6	1100	Suburban	No	No
102	609.6	15.9	API5L	X52	38	1000	Suburban	No	No
103	609.6	15.9	API5L	X52	38	830	Suburban	No	No
104	609.6	14.3	API5L	X52	38	1000	Suburban	No	No
105	609.6	14.3	API5L	X52	38	830	Suburban	No	No
106	609.6	12.7	API5L	X52	38	1000	Suburban	No	No
107	609.6	12.7	API5L	X52	38	900	Suburban	No	No
108	609.6	11.9	API5L	X52	38	1100	Suburban	No	No
109	609.6	11.9	API5L	X52	38	1000	Suburban	No	No
110	609.6	11.9	API5L	X52	38	830	Suburban	No	No
111	609.6	9.5	API5L	X52	38	1000	Rural	No	No
112	609.6	15.9	API5L	X46	37.2	1100	Suburban	No	No
113	609.6	12.7	API5L	X46	37.2	1100	Suburban	No	No
114	609.6	12.7	API5L	X46	37.2	910	Suburban	No	No
115	609.6	12.7	API5L	X46	37.2	900	Suburban	No	No
116	609.6	12.7	API5L	X46	37.2	800	Suburban	No	No
117	609.6	12.7	API5L	X46	37.2	600	Suburban	No	No
118	609.6	11.9	API5L	X52	37.2	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
119	609.6	9.5	API5L	X52	37.2	1100	Rural	No	No
120	609.6	9.5	API5L	X52	37.2	900	Rural	No	No
121	609.6	12.7	API5L	X46	37	1100	Suburban	No	No
122	609.6	11.9	API5L	X52	37	1100	Suburban	No	No
123	609.6	11.9	API5L	X52	37	1000	Suburban	No	No
124	609.6	12.7	API5L	X52	34.5	910	Suburban	No	No
125	609.6	11.9	API5L	X52	34.5	910	Suburban	No	No
126	609.6	9.5	API5L	X52	34.5	910	Rural	No	No
127	609.6	9.5	API5L	X52	33.8	1100	Rural	No	No
128	609.6	12.7	API5L	X52	33.1	1100	Suburban	No	No
129	609.6	12.7	API5L	X52	33.1	900	Suburban	No	No
130	609.6	9.5	API5L	X52	33.1	1100	Suburban	No	No
131	609.6	7.9	API5L	X42	33.1	900	Rural	No	No
132	609.6	11.1	API5L	X46	32.6	900	Suburban	No	No
133	609.6	11.9	API5L	X52	32.4	1100	Suburban	No	No
134	609.6	9.5	API5L	X52	32	1100	Suburban	No	No
135	609.6	11.9	API5L	X52	27.6	1100	Suburban	No	No
136	609.6	14.3	API5L	X60	26.2	1100	Suburban	No	No
137	609.6	9.5	API5L	X46	26.2	1100	Suburban	No	No
138	609.6	9.5	API5L	X46	26.2	910	Suburban	No	No
139	609.6	9.5	API5L	X52	26.2	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
140	609.6	9.5	API5L	X46	24	910	Suburban	No	No
141	609.6	9.5	API5L	X52	24	1100	Suburban	No	No
142	609.6	17.5	API5L	X60	19	1100	Suburban	No	No
143	609.6	15.9	API5L	X52	19	1100	Suburban	No	No
144	609.6	14.3	API5L	X52	19	1100	Suburban	No	No
145	609.6	9.5	API5L	X52	19	1000	Suburban	No	No
146	609.6	17.5	API5L	X52	13.9	830	Suburban	No	No
147	609.6	12.7	API5L	X52	13.9	1000	Suburban	No	No
148	609.6	12.7	API5L	X52	13.9	600	Suburban	No	No
149	609.6	11.9	API5L	X52	13.9	1000	Suburban	No	No
150	609.6	11.9	API5L	X52	13.9	830	Suburban	No	No
151	508	11.1	API5L	X46	70	900	Rural	No	No
152	508	11.1	API5L	X46	36.4	900	Suburban	No	No
153	508	11.1	API5L	X46	35.9	900	Suburban	No	No
154	508	9.5	API5L	X46	33.8	900	Suburban	No	No
155	508	11.1	API5L	X46	32.6	900	Suburban	No	No
156	508	9.5	API5L	B	19	1100	Suburban	No	No
157	508	9.5	API5L	X46	17.2	900	Suburban	No	No
158	457.2	11.9	API5L	X52	85	1100	Rural	No	No
159	457.2	15.9	API5L	X52	70	1100	Suburban	No	No
160	457.2	11.9	API5L	X52	70	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
161	457.2	11.9	API5L	X52	70	1000	Rural	No	No
162	457.2	11.9	API5L	X52	70	900	Rural	No	No
163	457.2	10.3	API5L	X52	70	1100	Rural	No	No
164	457.2	9.5	API5L	X52	70	1100	Rural	No	No
165	457.2	9.5	API5L	X52	70	1000	Rural	No	No
166	457.2	9.5	API5L	X52	70	900	Rural	No	No
167	457.2	11.9	API5L	X52	69	1000	Rural	No	No
168	457.2	11.9	API5L	X52	69	900	Rural	No	No
169	457.2	9.5	API5L	X52	69	1100	Rural	No	No
170	457.2	9.5	API5L	X52	69	1000	Rural	No	No
171	457.2	9.5	API5L	X52	69	900	Rural	No	No
172	457.2	9.5	API5L	X52	68.9	1100	Rural	No	No
173	457.2	9.5	API5L	X52	49.6	1100	Rural	No	No
174	457.2	10.3	API5L	X52	45.5	1000	Suburban	No	No
175	457.2	10.3	API5L	X46	42	1100	Suburban	No	No
176	457.2	10.3	API5L	X46	42	1000	Suburban	No	No
177	457.2	9.5	API5L	X52	42	1100	Suburban	No	No
178	457.2	8.7	API5L	X42	42	1100	Rural	No	No
179	457.2	10.3	API5L	X52	41.4	1100	Suburban	No	No
180	457.2	11.9	API5L	X52	39.3	900	Suburban	No	No
181	457.2	9.5	API5L	X52	39.3	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
182	457.2	9.5	API5L	X52	39.3	900	Suburban	No	No
183	457.2	11.9	API5L	X52	38	1100	Suburban	No	No
184	457.2	11.9	API5L	X52	38	900	Suburban	No	No
185	457.2	10.3	API5L	X46	38	1000	Suburban	No	No
186	457.2	10.3	API5L	X52	38	1000	Suburban	No	No
187	457.2	9.5	API5L	X52	38	1000	Suburban	No	No
188	457.2	9.5	API5L	X52	38	900	Suburban	No	No
189	457.2	10.3	API5L	X46	37.2	900	Suburban	No	No
190	457.2	10.3	API5L	X46	37.2	1100	Suburban	No	No
191	457.2	9.5	API5L	X46	37.2	1100	Suburban	No	No
192	457.2	11.9	API5L	X52	37	1000	Suburban	No	No
193	457.2	9.5	API5L	X52	36	1100	Suburban	No	No
194	457.2	9.5	API5L	X52	36	1000	Suburban	No	No
195	457.2	10.3	API5L	X46	34.5	910	Suburban	No	No
196	457.2	9.5	API5L	X52	33.8	1100	Suburban	No	No
197	457.2	10.3	API5L	X46	33.1	1100	Suburban	No	No
198	457.2	10.3	API5L	X46	33.1	900	Suburban	No	No
199	457.2	9.5	API5L	X46	33.1	900	Suburban	No	No
200	457.2	9.5	API5L	X52	33.1	1100	Suburban	No	No
201	457.2	9.5	API5L	X52	33.1	900	Suburban	No	No
202	457.2	9.5	API5L	X52	33.1	900	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
203	457.2	7.2	API5L	X46	33.1	1100	Rural	No	No
204	457.2	9.5	API5L	X46	32.6	900	Suburban	No	No
205	457.2	10.3	API5L	X46	32	1100	Suburban	No	No
206	457.2	9.5	API5L	X46	32	1100	Suburban	No	No
207	457.2	9.5	API5L	X52	32	1100	Suburban	No	No
208	457.2	9.5	API5L	X52	32	1000	Suburban	No	No
209	457.2	7.1	API5L	X52	32	1100	Suburban	No	No
210	457.2	6.4	API5L	X52	28	1100	Suburban	No	No
211	457.2	9.5	API5L	X52	27.6	1100	Suburban	No	No
212	457.2	9.5	API5L	X52	27.5	1100	Suburban	No	No
213	457.2	8.7	API5L	X42	27	1100	Suburban	No	No
214	457.2	9.5	API5L	X52	26.2	1100	Suburban	No	No
215	457.2	7.9	API5L	X46	26.2	1100	Suburban	No	No
216	457.2	8.9	API5L	B	24.1	1100	Suburban	No	No
217	457.2	7.9	API5L	B	24.1	1100	Suburban	No	No
218	457.2	9.5	API5L	X52	24	1100	Suburban	No	No
219	457.2	9.5	API5L	X52	24	1000	Suburban	No	No
220	457.2	7.9	API5L	X42	24	1100	Suburban	No	No
221	457.2	9.5	API5L	X52	22	1100	Suburban	No	No
222	457.2	9.5	API5L	X52	20.7	1100	Suburban	No	No
223	457.2	9.5	API5L	B	19	1000	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
224	457.2	6.4	API5L	B	19	1100	Suburban	No	No
225	457.2	6.4	API5L	B	19	900	Suburban	No	No
226	457.2	11.9	API5L	X52	19	900	Suburban	No	No
227	457.2	9.5	API5L	X52	19	1100	Suburban	No	No
228	457.2	10.3	API5L	X52	17	1000	Suburban	No	No
229	457.2	11.9	API5L	X52	15	1100	Suburban	No	No
230	457.2	11.9	API5L	X52	13.9	860	Suburban	No	No
231	406.4	15.9	API5L	X52	59	1100	Suburban	No	No
232	406.4	10.3	API5L	X42	38	1100	Suburban	No	No
233	406.4	10.3	API5L	X46	37.9	900	Suburban	No	No
234	406.4	7.9	API5L	X46	32.4	1100	Suburban	No	No
235	406.4	9.5	API5L	B	32	1100	Suburban	No	No
236	406.4	9.5	API5L	X46	32	1100	Suburban	No	No
237	406.4	9.5	API5L	X52	32	1100	Suburban	No	No
238	406.4	9.5	API5L	X56	32	1000	Suburban	No	No
239	406.4	7.9	API5L	X42	32	1100	Suburban	No	No
240	406.4	8.7	API5L	B	27	1100	Suburban	No	No
241	406.4	12.7	API5L	X52	26.2	1100	Suburban	No	No
242	406.4	7.9	API5L	X42	26.2	1100	Suburban	No	No
243	406.4	7.9	API5L	X42	26.2	910	Suburban	No	No
244	406.4	6.4	API5L	X42	26.2	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
245	406.4	9.5	API5L	X42	24	1100	Suburban	No	No
246	406.4	9.5	API5L	X46	24	1100	Suburban	No	No
247	406.4	8.2	API5L	B	24	1100	Suburban	No	No
248	406.4	10.3	API5L	X52	19	1100	Suburban	No	No
249	406.4	7.9	API5L	X42	19	900	Suburban	No	No
250	406.4	7.1	API5L	X42	19	1100	Suburban	No	No
251	355.6	7.9	API5L	X46	70	900	Rural	No	No
252	355.6	7.9	API5L	X46	37	1100	Suburban	No	No
253	355.6	7.9	API5L	X46	33.1	900	Suburban	No	No
254	355.6	7.9	API5L	X46	32.6	900	Suburban	No	No
255	355.6	8.2	API5L	X46	32	1100	Suburban	No	No
256	355.6	6.4	API5L	B	24.1	1000	Suburban	No	No
257	355.6	6.4	API5L	X46	10.3	900	Suburban	No	No
258	323.8	7.1	API5L	X46	75	1100	Rural	No	No
259	323.8	7.9	API5L	X52	70	1100	Rural	No	No
260	323.8	7.1	API5L	X42	70	1100	Rural	No	No
261	323.8	7.1	API5L	X46	70	1100	Rural	No	No
262	323.8	7.1	API5L	X46	70	1000	Rural	No	No
263	323.8	7.1	API5L	X46	69	1100	Rural	No	No
264	323.8	7.1	API5L	X46	69	900	Rural	No	No
265	323.8	7.1	API5L	X46	68.9	1100	Rural	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
266	323.8	7.1	API5L	X52	68.9	900	Rural	No	No
267	323.8	7.1	API5L	X46	48.3	1100	Rural	No	No
268	323.8	7.9	API5L	X52	46.2	900	Suburban	No	No
269	323.8	7.9	API5L	X52	43.8	900	Suburban	No	No
270	323.8	7.1	API5L	X46	43.8	900	Rural	No	No
271	323.8	7.1	API5L	X46	42	1100	Suburban	No	No
272	323.8	8.2	API5L	X52	41.4	1100	Suburban	No	No
273	323.8	7.1	API5L	X52	41.4	1100	Suburban	No	No
274	323.8	12.7	API5L	X52	40	1100	Suburban	No	No
275	323.8	8.4	API5L	X46	40	1100	Suburban	No	No
276	323.8	7.1	API5L	X46	40	1100	Suburban	No	No
277	323.8	9.5	API5L	X52	39.3	900	Suburban	No	No
278	323.8	7.1	API5L	X46	39.3	1100	Suburban	No	No
279	323.8	7.1	API5L	X52	39.3	900	Suburban	No	No
280	323.8	12.7	API5L	X52	38.6	700	Suburban	No	No
281	323.8	8.7	API5L	X46	38.6	1100	Suburban	No	No
282	323.8	7.1	API5L	X46	38.6	1100	Suburban	No	No
283	323.8	12.7	API5L	X52	38	1100	Suburban	No	No
284	323.8	7.9	API5L	X52	38	1000	Suburban	No	No
285	323.8	7.1	API5L	X46	38	1100	Suburban	No	No
286	323.8	7.1	API5L	X46	38	1000	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
287	323.8	7.1	API5L	X52	38	1000	Suburban	No	No
288	323.8	7.1	API5L	X52	38	900	Suburban	No	No
289	323.8	7.1	API5L	X52	38	860	Suburban	No	No
290	323.8	8.7	API5L	X46	37.2	1100	Suburban	No	No
291	323.8	7.1	API5L	X46	37.2	1100	Suburban	No	No
292	323.8	6.4	API5L	X46	37.2	1100	Suburban	No	No
293	323.8	6.4	API5L	X52	37.2	1100	Suburban	No	No
294	323.8	9.5	API5L	X46	37	1100	Suburban	No	No
295	323.8	7.1	API5L	X46	36.4	1100	Suburban	No	No
296	323.8	7.1	API5L	X52	36.4	1100	Suburban	No	No
297	323.8	9.5	API5L	X46	36	1100	Suburban	No	No
298	323.8	9.5	API5L	X52	36	1100	Suburban	No	No
299	323.8	7.1	API5L	X46	36	1100	Suburban	No	No
300	323.8	7.1	API5L	X46	34.5	910	Suburban	No	No
301	323.8	8.7	API5L	X46	33.1	900	Suburban	No	No
302	323.8	7.9	API5L	X46	33.1	900	Suburban	No	No
303	323.8	7.9	API5L	X52	33.1	1100	Suburban	No	No
304	323.8	7.9	API5L	X52	33.1	900	Suburban	No	No
305	323.8	7.1	API5L	X46	32.6	1100	Suburban	No	No
306	323.8	7.1	API5L	X46	32.6	900	Suburban	No	No
307	323.8	6.4	API5L	X46	32.6	900	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
308	323.8	6.4	API5L	X46	32.4	1100	Suburban	No	No
309	323.8	12.7	API5L	X52	32	1100	Suburban	No	No
310	323.8	9.5	API5L	X46	32	1100	Suburban	No	No
311	323.8	8.4	API5L	X42	32	1100	Suburban	No	No
312	323.8	8.4	API5L	X46	32	1100	Suburban	No	No
313	323.8	8.2	API5L	X42	32	1100	Suburban	No	No
314	323.8	8.2	API5L	X46	32	1100	Suburban	No	No
315	323.8	7.9	API5L	X52	32	1100	Suburban	No	No
316	323.8	7.1	API5L	X46	32	1100	Suburban	No	No
317	323.8	5.6	API5L	X52	32	1000	Suburban	No	No
318	323.8	7.1	API5L	X52	31	1100	Suburban	No	No
319	323.8	7.1	API5L	X46	27.6	1100	Suburban	No	No
320	323.8	7.1	API5L	X46	27.5	1100	Suburban	No	No
321	323.8	5.6	API5L	B	27.5	1100	Rural	No	No
322	323.8	7.1	API5L	X52	27	1100	Suburban	No	No
323	323.8	7.1	API5L	X46	26.4	1100	Suburban	No	No
324	323.8	12.7	API5L	X52	26.2	1100	Suburban	No	No
325	323.8	7.1	API5L	X46	26.2	1100	Suburban	No	No
326	323.8	6.4	API5L	B	26.2	1100	Suburban	No	No
327	323.8	5.5	API5L	X42	26.2	1100	Suburban	No	No
328	323.8	7.1	API5L	X46	24.8	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
329	323.8	12.7	API5L	X52	24.1	1100	Suburban	No	No
330	323.8	7.1	API5L	X46	24.1	1100	Suburban	No	No
331	323.8	7.1	API5L	X46	24.1	900	Suburban	No	No
332	323.8	6.4	API5L	B	24.1	1100	Suburban	No	No
333	323.8	6.4	API5L	B	24.1	1000	Suburban	No	No
334	323.8	6.4	API5L	X46	24.1	900	Suburban	No	No
335	323.8	6.4	API5L	X52	24.1	1000	Suburban	No	No
336	323.8	5.6	API5L	B	24.1	1100	Suburban	No	No
337	323.8	9.5	API5L	X46	24	1000	Suburban	No	No
338	323.8	8.4	API5L	X52	24	1100	Suburban	No	No
339	323.8	7.1	API5L	X46	24	1100	Suburban	No	No
340	323.8	6.4	API5L	X42	24	910	Suburban	No	No
341	323.8	5.1	API5L	B	24	1000	Rural	No	No
342	323.8	7.1	API5L	X46	20.9	1100	Suburban	No	No
343	323.8	6.4	API5L	B	20.7	900	Suburban	No	No
344	323.8	6.4	API5L	B	20.3	1000	Suburban	No	No
345	323.8	9.5	API5L	X52	19	1100	Suburban	No	No
346	323.8	8.7	API5L	X46	19	1100	Suburban	No	No
347	323.8	8.4	API5L	X42	19	1000	Suburban	No	No
348	323.8	8.4	API5L	X46	19	1100	Suburban	No	No
349	323.8	7.9	API5L	B	19	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
350	323.8	7.9	API5L	X52	19	900	Suburban	No	No
351	323.8	7.9	API5L	X52	19	1100	Suburban	No	No
352	323.8	7.1	API5L	B	19	900	Suburban	No	No
353	323.8	7.1	API5L	B	19	1100	Suburban	No	No
354	323.8	7.1	API5L	X42	19	1100	Suburban	No	No
355	323.8	7.1	API5L	X46	19	1000	Suburban	No	No
356	323.8	6.4	API5L	B	19	900	Suburban	No	No
357	323.8	6.4	API5L	B	19	1100	Suburban	No	No
358	323.8	6.4	API5L	B	19	1100	Suburban	No	No
359	323.8	6.4	API5L	B	19	1000	Suburban	No	No
360	323.8	6.4	API5L	B	19	900	Suburban	No	No
361	323.8	6.4	API5L	X46	19	1100	Suburban	No	No
362	323.8	6.4	API5L	X52	19	1100	Suburban	No	No
363	323.8	5.2	API5L	B	19	1100	Suburban	No	No
364	323.8	7.9	API5L	X52	19	900	Suburban	No	No
365	323.8	6.4	API5L	B	19	900	Suburban	No	No
366	323.8	7.9	API5L	X46	17.2	900	Suburban	No	No
367	323.8	7.1	API5L	X46	17	1100	Suburban	No	No
368	323.8	7.1	API5L	X46	17	1000	Suburban	No	No
369	323.8	7.1	API5L	X52	17	1100	Suburban	No	No
370	323.8	7.1	API5L	X52	17	1000	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
371	323.8	9.5	API5L	X46	15.2	1100	Suburban	No	No
372	323.8	6.4	API5L	X46	15.2	1100	Suburban	No	No
373	323.8	8.4	API5L	B	15	1100	Suburban	No	No
374	323.8	6.4	API5L	X42	15	1100	Suburban	No	No
375	323.8	6.4	API5L	B	14	1000	Suburban	No	No
376	323.8	6.4	API5L	B	14	750	Suburban	No	No
377	323.8	6.4	API5L	B	13.7	1000	Suburban	No	No
378	323.8	6.4	API5L	X46	12.4	1100	Suburban	No	No
379	323.8	6.4	API5L	X46	9.3	1100	Suburban	No	No
380	323.8	6.4	API5L	B	8.5	1100	Suburban	No	No
381	323.8	6.4	API5L	X46	8.3	900	Suburban	No	No
382	273	6.4	API5L	X46	75	1100	Rural	No	No
383	273	6.4	API5L	X46	70	1100	Rural	No	No
384	273	6.4	API5L	X52	70	900	Rural	No	No
385	273	6.4	API5L	X46	69	1100	Rural	No	No
386	273	6.4	API5L	X46	69	1000	Rural	No	No
387	273	12.7	API5L	X46	67	1100	Suburban	No	No
388	273	6.4	API5L	X52	43.8	1000	Suburban	No	No
389	273	12.7	API5L	X46	42	1100	Suburban	No	No
390	273	12.7	API5L	X46	42	1000	Suburban	No	No
391	273	6.4	API5L	X46	39.3	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
392	273	6.4	API5L	X52	39.3	1100	Suburban	No	No
393	273	7.9	API5L	X46	38.6	900	Suburban	No	No
394	273	7.1	API5L	X46	38	900	Suburban	No	No
395	273	6.4	API5L	X46	38	1100	Suburban	No	No
396	273	6.4	API5L	X46	38	1000	Suburban	No	No
397	273	7.9	API5L	X46	37.2	1100	Suburban	No	No
398	273	6.4	API5L	X46	37.2	1100	Suburban	No	No
399	273	6.4	API5L	X46	36.5	1100	Suburban	No	No
400	273	6.4	API5L	X46	32.6	900	Suburban	No	No
401	273	7.9	API5L	X42	32	1100	Suburban	No	No
402	273	6.4	API5L	B	24.1	1100	Suburban	No	No
403	273	7.1	API5L	X52	24	1100	Suburban	No	No
404	273	7.1	API5L	X52	24	1000	Suburban	No	No
405	273	6.4	API5L	B	24	1000	Suburban	No	No
406	273	6.4	API5L	B	19	1100	Suburban	No	No
407	273	6.4	API5L	B	19	1000	Suburban	No	No
408	273	6.4	API5L	X46	19	900	Suburban	No	No
409	273	6.4	API5L	X46	19	1100	Suburban	No	No
410	273	7.8	API5L	X52	19	900	Suburban	No	No
411	273	7.1	API5L	B	19	900	Suburban	No	No
412	273	6.4	API5L	B	19	900	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
413	273	6.4	API5L	B	19	600	Suburban	No	No
414	273	6.4	API5L	X42	19	1100	Suburban	No	No
415	273	6.4	API5L	X46	19	1100	Suburban	No	No
416	273	6.4	API5L	X46	19	1100	Suburban	No	No
417	273	6.4	API5L	X46	19	1000	Suburban	No	No
418	273	6.4	API5L	X46	19	900	Suburban	No	No
419	273	6.4	API5L	X52	19	900	Suburban	No	No
420	273	6.4	API5L	X46	17.2	1100	Suburban	No	No
421	273	7.1	API5L	X46	17	1000	Suburban	No	No
422	273	6.4	API5L	X46	15	1100	Suburban	No	No
423	273	5.6	API5L	B	13.7	1100	Suburban	No	No
424	219.1	6.4	API5L	X42	75	1100	Rural	No	No
425	219.1	6.4	API5L	X42	70	1100	Rural	No	No
426	219.1	6.4	API5L	X46	70	1100	Rural	No	No
427	219.1	5.6	API5L	X52	70	1100	Rural	No	No
428	219.1	8.2	API5L	X42	69	1100	Rural	No	No
429	219.1	6.4	API5L	X42	69	1100	Rural	No	No
430	219.1	6.4	API5L	X46	69	900	Rural	No	No
431	219.1	12.7	API5L	X42	67	1100	Suburban	No	No
432	219.1	6.4	API5L	X42	67	1100	Rural	No	No
433	219.1	6.4	API5L	X42	49.7	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
434	219.1	6.4	API5L	X42	49.6	1100	Suburban	No	No
435	219.1	6.4	API5L	X42	48.3	1100	Suburban	No	No
436	219.1	6.4	API5L	X52	46.2	900	Suburban	No	No
437	219.1	6.4	API5L	X46	43.8	900	Suburban	No	No
438	219.1	6.4	API5L	X52	43.8	900	Suburban	No	No
439	219.1	6.4	API5L	X42	42	1100	Suburban	No	No
440	219.1	6.4	API5L	X42	41.4	1100	Suburban	No	No
441	219.1	6.4	API5L	X42	39.3	1100	Suburban	No	No
442	219.1	6.4	API5L	X42	39.3	900	Suburban	No	No
443	219.1	6.4	API5L	X52	39.3	900	Suburban	No	No
444	219.1	6.4	API5L	X42	38.6	1100	Suburban	No	No
445	219.1	7.1	API5L	X42	38	900	Suburban	No	No
446	219.1	6.4	API5L	X42	38	1100	Suburban	No	No
447	219.1	7.1	API5L	X46	37.2	1100	Suburban	No	No
448	219.1	6.4	API5L	X42	37.2	1100	Suburban	No	No
449	219.1	6.4	API5L	X46	37.2	1100	Suburban	No	No
450	219.1	6.4	API5L	X46	36.4	900	Suburban	No	No
451	219.1	7.1	API5L	B	36	1100	Suburban	No	No
452	219.1	6.4	API5L	X42	36	1100	Suburban	No	No
453	219.1	6.4	API5L	X46	35.9	900	Suburban	No	No
454	219.1	8.2	API5L	X42	34.5	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
455	219.1	6.4	API5L	X46	34.4	1100	Suburban	No	No
456	219.1	6.3	API5L	B	33.7	1100	Suburban	No	No
457	219.1	7.1	API5L	X42	33.1	900	Suburban	No	No
458	219.1	6.4	API5L	X42	33.1	900	Suburban	No	No
459	219.1	6.4	API5L	X42	32.4	1100	Suburban	No	No
460	219.1	8.2	API5L	X42	32	1100	Suburban	No	No
461	219.1	7.1	API5L	X52	32	1100	Suburban	No	No
462	219.1	6.4	API5L	X42	32	1100	Suburban	No	No
463	219.1	6.4	API5L	X46	32	1100	Suburban	No	No
464	219.1	5.5	API5L	X52	32	1100	Suburban	No	No
465	219.1	8.2	API5L	X42	27.5	1100	Suburban	No	No
466	219.1	6.4	API5L	X42	27.5	1100	Suburban	No	No
467	219.1	6.4	API5L	B	26.2	910	Suburban	No	No
468	219.1	6.4	API5L	X42	26.2	1100	Suburban	No	No
469	219.1	6.4	API5L	X42	26	1100	Suburban	No	No
470	219.1	6.4	API5L	X42	24.8	1100	Suburban	No	No
471	219.1	4.4	API5L	B	24.8	1100	Suburban	No	No
472	219.1	6.4	API5L	X42	24.1	1100	Suburban	No	No
473	219.1	6.4	API5L	X42	24.1	600	Suburban	No	No
474	219.1	5.5	API5L	X42	24.1	1100	Suburban	No	No
475	219.1	4.8	API5L	B	24.1	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
476	219.1	4.8	API5L	X52	24.1	1100	Suburban	No	No
477	219.1	4.8	API5L	X52	24.1	900	Suburban	No	No
478	219.1	7.9	API5L	X42	24	900	Suburban	No	No
479	219.1	7.1	API5L	X42	24	1000	Suburban	No	No
480	219.1	7.1	API5L	X52	24	1100	Suburban	No	No
481	219.1	6.4	API5L	X42	24	1100	Suburban	No	No
482	219.1	6.4	API5L	X42	24	910	Suburban	No	No
483	219.1	6.4	API5L	X46	24	1000	Suburban	No	No
484	219.1	5.5	API5L	X52	24	1100	Suburban	No	No
485	219.1	5.1	API5L	B	24	1000	Suburban	No	No
486	219.1	6.4	API5L	X42	22	1100	Suburban	No	No
487	219.1	4.8	API5L	B	21.4	1100	Suburban	No	No
488	219.1	6.4	API5L	X42	20.9	1100	Suburban	No	No
489	219.1	6.4	API5L	X42	20	1100	Suburban	No	No
490	219.1	6.4	API5L	B	19	900	Suburban	No	No
491	219.1	6.4	API5L	B	19	1100	Suburban	No	No
492	219.1	6.4	API5L	B	19	1000	Suburban	No	No
493	219.1	6.4	API5L	B	19	900	Suburban	No	No
494	219.1	6.4	API5L	X42	19	1100	Suburban	No	No
495	219.1	6.4	API5L	X46	19	1100	Suburban	No	No
496	219.1	6.4	API5L	X46	19	1000	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
497	219.1	5.5	API5L	B	19	1000	Suburban	No	No
498	219.1	5.5	API5L	X42	19	1100	Suburban	No	No
499	219.1	4.8	API5L	B	19	1100	Suburban	No	No
500	219.1	4.8	API5L	B	19	1000	Suburban	No	No
501	219.1	6.4	API5L	X46	19	900	Suburban	No	No
502	219.1	6.4	API5L	X52	19	900	Suburban	No	No
503	219.1	4.8	API5L	B	19	900	Suburban	No	No
504	219.1	6.4	API5L	X42	17.2	1100	Suburban	No	No
505	219.1	6.4	API5L	X46	17.2	1100	Suburban	No	No
506	219.1	4.8	API5L	B	17.2	1100	Suburban	No	No
507	219.1	6.4	API5L	X46	17	1000	Suburban	No	No
508	219.1	5.2	API5L	X42	15	1100	Suburban	No	No
509	219.1	4.8	API5L	B	15	1100	Suburban	No	No
510	219.1	6.4	API5L	X42	14	1000	Suburban	No	No
511	219.1	6.4	API5L	X42	13.8	1100	Suburban	No	No
512	219.1	6.4	API5L	B	13.7	1100	Suburban	No	No
513	168.3	7.1	API5L	X42	70	1100	Suburban	No	No
514	168.3	6.4	API5L	X42	70	1100	Rural	No	No
515	168.3	5.6	API5L	X42	70	1100	Rural	No	No
516	168.3	4.4	API5L	X52	70	1100	Rural	No	No
517	168.3	7.1	API5L	X42	69	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
518	168.3	7.1	API5L	X42	69	900	Suburban	No	No
519	168.3	6.4	API5L	X52	69	900	Suburban	No	No
520	168.3	5.6	API5L	X42	69	1100	Rural	No	No
521	168.3	5.5	API5L	X42	69	1100	Rural	No	No
522	168.3	7.1	API5L	X46	68.9	1100	Suburban	No	No
523	168.3	5.6	API5L	X42	68.9	1100	Rural	No	No
524	168.3	5.6	API5L	X46	68.9	1100	Rural	No	No
525	168.3	4.8	API5L	X46	68.9	1100	Rural	No	No
526	168.3	5.6	API5L	X42	49.6	1100	Suburban	No	No
527	168.3	5.6	API5L	X42	48.3	1100	Suburban	No	No
528	168.3	7.1	API5L	X42	46.2	900	Suburban	No	No
529	168.3	5.6	API5L	X46	46.2	900	Suburban	No	No
530	168.3	7.1	API5L	X42	43.8	1100	Suburban	No	No
531	168.3	6.4	API5L	X52	43.8	1000	Suburban	No	No
532	168.3	5.5	API5L	X42	43.8	1100	Suburban	No	No
533	168.3	5.1	API5L	B	42	1100	Suburban	No	No
534	168.3	5.6	API5L	X42	41.4	1100	Suburban	No	No
535	168.3	7.1	API5L	X46	39.3	700	Suburban	No	No
536	168.3	7.1	API5L	X42	38	1100	Suburban	No	No
537	168.3	7.1	API5L	X42	38	1000	Suburban	No	No
538	168.3	7.1	API5L	X42	38	900	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
539	168.3	6.4	API5L	X52	38	1000	Suburban	No	No
540	168.3	5.6	API5L	X42	38	1000	Suburban	No	No
541	168.3	5.6	API5L	X52	38	900	Suburban	No	No
542	168.3	4.8	API5L	X52	38	900	Suburban	No	No
543	168.3	7.1	API5L	X42	37.2	1100	Suburban	No	No
544	168.3	5.6	API5L	X42	37.2	1100	Suburban	No	No
545	168.3	5.6	API5L	X42	37	1000	Suburban	No	No
546	168.3	6.4	API5L	X46	36.4	900	Suburban	No	No
547	168.3	5.6	API5L	X42	36	1100	Suburban	No	No
548	168.3	6.4	API5L	X46	33.1	900	Suburban	No	No
549	168.3	6.4	API5L	X46	32	1000	Suburban	No	No
550	168.3	6.4	API5L	X52	32	1100	Suburban	No	No
551	168.3	5.6	API5L	X42	32	1100	Suburban	No	No
552	168.3	4.6	API5L	X52	32	1100	Suburban	No	No
553	168.3	7.1	API5L	X42	27.6	1100	Suburban	No	No
554	168.3	5.2	API5L	X52	27.6	900	Suburban	No	No
555	168.3	7.1	API5L	X42	27.5	1100	Suburban	No	No
556	168.3	5.6	API5L	X42	27.5	1100	Suburban	No	No
557	168.3	5.6	API5L	X42	24.1	1100	Suburban	No	No
558	168.3	5.6	API5L	X46	24.1	1100	Suburban	No	No
559	168.3	4.8	API5L	B	24.1	1100	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
560	168.3	4.6	API5L	B	24.1	1100	Suburban	No	No
561	168.3	4.6	API5L	B	24.1	1000	Suburban	No	No
562	168.3	4.4	API5L	B	24.1	1100	Suburban	No	No
563	168.3	4.4	API5L	B	24.1	800	Suburban	No	No
564	168.3	5.6	API5L	X42	24	1100	Suburban	No	No
565	168.3	5.1	API5L	B	24	1000	Suburban	No	No
566	168.3	6.4	API5L	X42	19	1100	Suburban	No	No
567	168.3	5.6	API5L	B	19	1100	Suburban	No	No
568	168.3	5.6	API5L	B	19	1000	Suburban	No	No
569	168.3	5.6	API5L	B	19	900	Suburban	No	No
570	168.3	4.8	API5L	B	19	900	Suburban	No	No
571	168.3	6.4	API5L	B	17.2	1100	Suburban	No	No
572	168.3	6.4	API5L	X46	9.3	1100	Suburban	No	No
573	114.3	6.4	API5L	B	70	1100	Suburban	No	No
574	114.3	4.8	API5L	B	70	1100	Rural	No	No
575	114.3	6	API5L	B	69	1100	Suburban	No	No
576	114.3	4.8	API5L	B	69	1100	Rural	No	No
577	114.3	4.8	API5L	B	49.6	1100	Suburban	No	No
578	114.3	6	API5L	B	43.8	900	Suburban	No	No
579	114.3	7.1	API5L	B	32	1100	Suburban	No	No
580	114.3	6	API5L	X42	19	900	Suburban	No	No

Pipeline	Pipe Diameter (mm)	Pipe Wall Thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
581	114.3	6	API5L	X42	19	1100	Suburban	No	No
582	114.3	6	API5L	X42	19	1000	Suburban	No	No
583	114.3	6	API5L	X46	17	1000	Suburban	No	No
584	88.9	5.5	API5L	B	34.5	600	Suburban	No	No

12.2 Non-natural gas pipelines

Table 14 Parameters of the pipelines that form the non-natural gas test set

Pipeline	Substance	Pipe diameter (mm)	Pipe wall thickness (mm)	Material Code	Material Grade	Pressure (barg)	Depth Of Cover (mm)	Location	Slabs	Tapes
9669	Ethylene	323.9	6.4	API5L	X60	102	1000	Rural	No	No
11906	Propane	114	8.6	API5L	B	17.5	900	Suburban	No	No
11885	N-butane	219	7	API5L	B	20	900	Suburban	No	No
11886	Propane	168.2	7.1	API5L	B	20	900	Suburban	No	No
7129	Ethylene	273	5.65	API5L	X52	98	900	Rural	No	No
10021	Ethylene	219	7.9	API5L	A	45	900	Rural	No	No
6799	Propylene	100	6	API5L	A	50	900	Suburban	No	No
7335	Ethylene	200	11	API5L	X42	94	1200	Suburban	No	No
12855	Ethylene	219.08	7.92	API5L	X42	99.3	1200	Rural	No	No
6978	Propane	168.3	7.14	API5L	X42	19.6	900	Suburban	No	No
12592	Propane	114	5.02	API5L	X42	19	1000	Suburban	No	No
6713	Ethylene	203	9.52	API5L	X42	93	1600	Rural	No	No
8395	Propane	114.3	6.02	BS3601	L320	13.5	760	Suburban	No	No
6904	Ethylene	273	7.08	API5L	X52	97.9	1500	Rural	No	No
7338	Propane	457	8	API5L	X42	40	1200	Rural	No	No
7340	N-butane	457	8	API5L	X42	40	1200	Rural	No	No
6802	Ethylene	219	7.9	API5L	X42	80	900	Rural	No	No

13 Appendix 3 Methane failure rates

This section provides the detailed methane pipeline failure rate results. Section 13.1 contains the results using V3.04 of PIPIN, Section 13.2 contains the results from V3.1 of PIPIN and Section 13.3 compares both sets of results.

13.1 V3.04 of PIPIN

Table 15 Failure rates for methane calculated using V3.04 of PIPIN

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
1	2.58E-09	1.72E-10	2.53E-09	2.10E-08
2	2.77E-09	1.78E-10	2.56E-09	2.15E-08
3	2.95E-09	1.83E-10	2.59E-09	2.19E-08
4	3.27E-09	1.91E-10	2.63E-09	2.25E-08
5	2.93E-09	1.83E-10	2.59E-09	2.20E-08
6	2.86E-09	1.81E-10	2.58E-09	2.18E-08
7	3.77E-09	2.04E-10	2.69E-09	2.36E-08
8	3.84E-09	2.23E-10	2.78E-09	2.47E-08
9	2.63E-09	1.79E-10	2.57E-09	2.17E-08
10	4.26E-09	2.11E-10	2.73E-09	2.41E-08
11	3.80E-09	2.04E-10	2.69E-09	2.36E-08
12	3.49E-09	1.99E-10	2.67E-09	2.32E-08
13	3.27E-09	1.94E-10	2.64E-09	2.28E-08
14	2.55E-09	1.73E-10	2.54E-09	2.12E-08
15	3.15E-09	2.26E-10	2.81E-09	2.55E-08
16	3.95E-09	3.11E-10	3.23E-09	3.15E-08
17	6.24E-09	2.50E-10	2.92E-09	2.67E-08
18	2.84E-09	1.81E-10	2.58E-09	2.19E-08
19	4.80E-09	2.31E-10	2.83E-09	2.53E-08
20	5.04E-09	2.37E-10	2.86E-09	2.58E-08
21	5.32E-09	2.45E-10	2.90E-09	2.64E-08
22	4.33E-09	2.22E-10	2.78E-09	2.47E-08
23	2.85E-09	1.82E-10	2.58E-09	2.19E-08
24	2.73E-09	1.78E-10	2.56E-09	2.16E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
25	2.76E-09	1.79E-10	2.57E-09	2.17E-08
26	2.78E-09	1.80E-10	2.57E-09	2.18E-08
27	3.14E-09	1.91E-10	2.63E-09	2.26E-08
28	4.35E-09	2.25E-10	2.80E-09	2.49E-08
29	4.35E-09	2.25E-10	2.80E-09	2.49E-08
30	4.77E-09	2.37E-10	2.86E-09	2.58E-08
31	4.77E-09	2.37E-10	2.86E-09	2.58E-08
32	4.77E-09	2.37E-10	2.86E-09	2.58E-08
33	4.78E-09	2.37E-10	2.86E-09	2.58E-08
34	2.63E-09	1.76E-10	2.55E-09	2.14E-08
35	3.23E-09	2.10E-10	2.72E-09	2.39E-08
36	3.05E-09	2.07E-10	2.71E-09	2.36E-08
37	3.11E-09	2.11E-10	2.73E-09	2.40E-08
38	4.03E-09	3.00E-10	3.18E-09	3.08E-08
39	8.71E-09	5.65E-10	4.40E-09	7.55E-08
40	3.54E-09	2.83E-10	3.09E-09	2.95E-08
41	3.96E-09	2.16E-10	2.75E-09	2.43E-08
42	4.12E-09	2.21E-10	2.78E-09	2.47E-08
43	6.34E-09	2.68E-10	3.01E-09	2.78E-08
44	4.57E-09	2.34E-10	2.84E-09	2.54E-08
45	2.74E-09	1.79E-10	2.57E-09	2.16E-08
46	3.76E-09	2.14E-10	2.74E-09	2.42E-08
47	4.04E-09	2.24E-10	2.79E-09	2.49E-08
48	4.04E-09	2.24E-10	2.79E-09	2.49E-08
49	5.65E-09	2.60E-10	2.97E-09	2.73E-08
50	5.99E-09	2.70E-10	3.02E-09	2.80E-08
51	6.37E-09	2.81E-10	3.07E-09	2.87E-08
52	4.65E-09	2.39E-10	2.87E-09	2.58E-08
53	2.81E-09	1.93E-10	2.64E-09	2.30E-08
54	2.76E-09	1.91E-10	2.63E-09	2.28E-08
55	3.07E-09	2.08E-10	2.71E-09	2.38E-08
56	3.48E-09	2.32E-10	2.83E-09	2.54E-08
57	2.74E-09	1.90E-10	2.63E-09	2.28E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
58	2.76E-09	1.93E-10	2.64E-09	2.30E-08
59	2.79E-09	1.95E-10	2.65E-09	2.32E-08
60	4.11E-09	2.95E-10	3.15E-09	3.05E-08
61	4.29E-09	3.08E-10	3.22E-09	3.16E-08
62	4.29E-09	3.08E-10	3.22E-09	3.16E-08
63	3.42E-09	2.31E-10	2.83E-09	2.53E-08
64	3.52E-09	2.38E-10	2.86E-09	2.58E-08
65	3.15E-09	2.23E-10	2.79E-09	2.54E-08
66	2.64E-09	1.84E-10	2.59E-09	2.22E-08
67	3.88E-09	2.92E-10	3.14E-09	3.04E-08
68	4.18E-09	3.20E-10	3.28E-09	3.25E-08
69	3.74E-09	2.84E-10	3.10E-09	2.97E-08
70	3.66E-09	2.80E-10	3.08E-09	2.94E-08
71	5.06E-09	3.84E-10	3.59E-09	3.66E-08
72	6.73E-09	6.48E-10	4.88E-09	5.31E-08
73	8.12E-09	8.85E-10	5.98E-09	9.70E-08
74	2.81E-09	2.51E-10	2.93E-09	2.68E-08
75	5.38E-09	2.61E-10	2.98E-09	2.75E-08
76	1.45E-08	4.56E-10	3.90E-09	7.07E-08
77	2.93E-09	1.87E-10	2.61E-09	2.24E-08
78	5.00E-09	2.57E-10	2.96E-09	2.73E-08
79	4.54E-09	2.41E-10	2.88E-09	2.61E-08
80	4.76E-09	2.48E-10	2.91E-09	2.66E-08
81	4.99E-09	2.57E-10	2.96E-09	2.72E-08
82	1.28E-08	4.44E-10	3.84E-09	7.00E-08
83	1.52E-08	5.07E-10	4.15E-09	7.38E-08
84	1.25E-08	4.42E-10	3.84E-09	7.00E-08
85	1.25E-08	4.41E-10	3.83E-09	6.99E-08
86	8.23E-09	4.14E-10	3.70E-09	6.86E-08
87	3.27E-09	2.23E-10	2.79E-09	2.55E-08
88	3.36E-09	2.28E-10	2.82E-09	2.60E-08
89	3.17E-09	2.10E-10	2.72E-09	2.40E-08
90	7.92E-09	4.11E-10	3.69E-09	6.85E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
91	5.42E-09	3.62E-10	3.48E-09	3.52E-08
92	4.25E-09	2.97E-10	3.17E-09	3.09E-08
93	3.50E-09	2.32E-10	2.83E-09	2.55E-08
94	5.58E-09	3.81E-10	3.58E-09	3.67E-08
95	5.92E-09	4.04E-10	3.70E-09	3.84E-08
96	5.93E-09	4.04E-10	3.70E-09	3.84E-08
97	6.84E-09	4.02E-10	3.65E-09	6.80E-08
98	5.31E-09	3.74E-10	3.55E-09	3.62E-08
99	6.50E-09	3.98E-10	3.63E-09	6.77E-08
100	5.53E-09	3.94E-10	3.65E-09	3.77E-08
101	5.13E-09	3.70E-10	3.52E-09	3.58E-08
102	2.67E-09	1.86E-10	2.60E-09	2.24E-08
103	2.70E-09	1.89E-10	2.62E-09	2.27E-08
104	3.01E-09	2.16E-10	2.76E-09	2.49E-08
105	3.10E-09	2.25E-10	2.81E-09	2.57E-08
106	4.08E-09	3.01E-10	3.19E-09	3.13E-08
107	4.25E-09	3.15E-10	3.26E-09	3.24E-08
108	5.03E-09	3.66E-10	3.51E-09	3.56E-08
109	5.32E-09	3.89E-10	3.62E-09	3.73E-08
110	5.84E-09	4.29E-10	3.82E-09	4.03E-08
111	6.58E-09	4.18E-10	3.73E-09	6.90E-08
112	2.69E-09	1.87E-10	2.61E-09	2.25E-08
113	4.20E-09	3.04E-10	3.20E-09	3.16E-08
114	4.56E-09	3.33E-10	3.35E-09	3.38E-08
115	4.58E-09	3.35E-10	3.36E-09	3.40E-08
116	4.80E-09	3.53E-10	3.45E-09	3.54E-08
117	5.33E-09	3.95E-10	3.66E-09	3.88E-08
118	4.93E-09	3.63E-10	3.49E-09	3.54E-08
119	6.07E-09	3.92E-10	3.60E-09	6.74E-08
120	6.88E-09	4.44E-10	3.85E-09	7.06E-08
121	4.18E-09	3.04E-10	3.20E-09	3.15E-08
122	4.90E-09	3.63E-10	3.49E-09	3.53E-08
123	5.16E-09	3.84E-10	3.60E-09	3.69E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
124	3.91E-09	3.02E-10	3.19E-09	3.13E-08
125	5.04E-09	3.93E-10	3.64E-09	3.76E-08
126	6.32E-09	4.32E-10	3.79E-09	6.99E-08
127	5.54E-09	3.84E-10	3.56E-09	6.69E-08
128	3.56E-09	2.74E-10	3.05E-09	2.91E-08
129	3.80E-09	2.98E-10	3.17E-09	3.10E-08
130	1.39E-08	9.98E-10	6.54E-09	1.05E-07
131	1.79E-08	9.34E-10	6.12E-09	9.38E-08
132	7.58E-09	5.84E-10	4.58E-09	5.01E-08
133	4.34E-09	3.44E-10	3.39E-09	3.39E-08
134	1.32E-08	9.84E-10	6.47E-09	1.04E-07
135	3.80E-09	3.20E-10	3.28E-09	3.21E-08
136	2.66E-09	1.92E-10	2.63E-09	2.27E-08
137	1.15E-08	9.86E-10	6.48E-09	1.04E-07
138	1.34E-08	1.16E-09	7.33E-09	1.15E-07
139	1.00E-08	9.03E-10	6.08E-09	9.90E-08
140	1.18E-08	1.11E-09	7.09E-09	1.12E-07
141	8.87E-09	8.62E-10	5.88E-09	9.64E-08
142	2.52E-09	1.71E-10	2.53E-09	2.09E-08
143	2.54E-09	1.75E-10	2.55E-09	2.13E-08
144	2.59E-09	1.87E-10	2.61E-09	2.23E-08
145	6.95E-09	8.17E-10	5.66E-09	9.36E-08
146	2.52E-09	1.71E-10	2.53E-09	2.09E-08
147	2.65E-09	2.09E-10	2.72E-09	2.39E-08
148	2.71E-09	2.29E-10	2.82E-09	2.54E-08
149	2.78E-09	2.43E-10	2.89E-09	2.63E-08
150	2.83E-09	2.57E-10	2.96E-09	2.73E-08
151	6.66E-09	3.08E-10	3.21E-09	3.07E-08
152	7.27E-09	5.46E-10	4.40E-09	4.80E-08
153	7.13E-09	5.42E-10	4.38E-09	4.77E-08
154	1.62E-08	1.17E-09	7.41E-09	1.17E-07
155	6.29E-09	5.16E-10	4.24E-09	4.57E-08
156	8.05E-09	8.73E-10	5.94E-09	9.80E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
157	6.01E-09	7.80E-10	5.49E-09	9.19E-08
158	4.38E-09	2.32E-10	2.83E-09	2.56E-08
159	2.85E-09	1.89E-10	2.62E-09	2.27E-08
160	3.84E-09	2.26E-10	2.81E-09	2.52E-08
161	3.98E-09	2.32E-10	2.84E-09	2.56E-08
162	4.14E-09	2.40E-10	2.87E-09	2.62E-08
163	6.48E-09	3.15E-10	3.24E-09	3.06E-08
164	9.33E-09	3.99E-10	3.63E-09	6.80E-08
165	1.01E-08	4.24E-10	3.76E-09	6.96E-08
166	1.09E-08	4.51E-10	3.89E-09	7.13E-08
167	3.95E-09	2.32E-10	2.84E-09	2.56E-08
168	4.10E-09	2.39E-10	2.87E-09	2.61E-08
169	9.20E-09	3.98E-10	3.63E-09	6.80E-08
170	9.92E-09	4.23E-10	3.75E-09	6.96E-08
171	1.07E-08	4.50E-10	3.89E-09	7.13E-08
172	9.18E-09	3.98E-10	3.63E-09	6.80E-08
173	6.50E-09	3.78E-10	3.54E-09	6.69E-08
174	1.09E-08	6.99E-10	5.13E-09	5.68E-08
175	1.04E-08	6.80E-10	5.04E-09	5.56E-08
176	1.13E-08	7.37E-10	5.32E-09	5.95E-08
177	1.43E-08	9.31E-10	6.23E-09	1.02E-07
178	9.99E-09	5.41E-10	4.30E-09	7.55E-08
179	8.85E-09	6.22E-10	4.75E-09	5.16E-08
180	4.58E-09	3.53E-10	3.44E-09	3.50E-08
181	1.30E-08	9.06E-10	6.11E-09	1.00E-07
182	1.54E-08	1.07E-09	6.93E-09	1.11E-07
183	4.09E-09	3.15E-10	3.25E-09	3.21E-08
184	4.45E-09	3.48E-10	3.42E-09	3.46E-08
185	9.77E-09	7.04E-10	5.16E-09	5.73E-08
186	8.48E-09	6.44E-10	4.86E-09	5.31E-08
187	1.35E-08	9.71E-10	6.43E-09	1.05E-07
188	1.47E-08	1.06E-09	6.85E-09	1.10E-07
189	1.02E-08	7.54E-10	5.41E-09	6.07E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
190	8.80E-09	6.44E-10	4.87E-09	5.32E-08
191	1.40E-08	9.64E-10	6.40E-09	1.04E-07
192	4.16E-09	3.27E-10	3.31E-09	3.30E-08
193	1.16E-08	8.74E-10	5.96E-09	9.84E-08
194	1.25E-08	9.49E-10	6.32E-09	1.03E-07
195	9.09E-09	7.17E-10	5.22E-09	5.81E-08
196	1.06E-08	8.46E-10	5.82E-09	9.66E-08
197	7.50E-09	6.07E-10	4.68E-09	5.06E-08
198	8.64E-09	7.08E-10	5.18E-09	5.75E-08
199	1.39E-08	1.08E-09	6.98E-09	1.12E-07
200	1.03E-08	8.39E-10	5.78E-09	9.62E-08
201	1.20E-08	9.92E-10	6.53E-09	1.06E-07
202	1.20E-08	9.93E-10	6.54E-09	1.06E-07
203	1.57E-08	9.40E-10	6.11E-09	9.21E-08
204	1.36E-08	1.07E-09	6.93E-09	1.11E-07
205	7.16E-09	5.96E-10	4.63E-09	4.99E-08
206	1.12E-08	8.98E-10	6.07E-09	1.00E-07
207	9.78E-09	8.23E-10	5.71E-09	9.52E-08
208	1.06E-08	8.97E-10	6.07E-09	9.98E-08
209	4.79E-08	3.15E-09	1.64E-08	2.01E-07
210	6.53E-08	4.48E-09	2.22E-08	2.48E-07
211	8.01E-09	7.62E-10	5.41E-09	9.13E-08
212	7.95E-09	7.60E-10	5.40E-09	9.11E-08
213	1.61E-08	1.37E-09	8.29E-09	1.24E-07
214	7.47E-09	7.40E-10	5.30E-09	8.98E-08
215	2.38E-08	2.03E-09	1.13E-08	1.55E-07
216	1.51E-08	1.31E-09	8.05E-09	1.23E-07
217	2.99E-08	2.31E-09	1.26E-08	1.70E-07
218	6.65E-09	7.02E-10	5.11E-09	8.74E-08
219	7.09E-09	7.59E-10	5.39E-09	9.10E-08
220	2.33E-08	2.07E-09	1.15E-08	1.57E-07
221	5.96E-09	6.64E-10	4.93E-09	8.49E-08
222	5.54E-09	6.38E-10	4.80E-09	8.32E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
223	7.66E-09	8.69E-10	5.93E-09	9.81E-08
224	6.04E-08	4.91E-09	2.42E-08	2.69E-07
225	7.35E-08	5.99E-09	2.92E-08	3.18E-07
226	2.88E-09	2.50E-10	2.92E-09	2.69E-08
227	5.03E-09	6.02E-10	4.63E-09	8.10E-08
228	3.55E-09	3.96E-10	3.63E-09	3.60E-08
229	2.68E-09	2.18E-10	2.76E-09	2.44E-08
230	2.68E-09	2.25E-10	2.80E-09	2.50E-08
231	2.70E-09	1.83E-10	2.59E-09	2.22E-08
232	8.86E-09	6.38E-10	4.84E-09	5.32E-08
233	9.19E-09	6.99E-10	5.14E-09	5.74E-08
234	2.87E-08	2.05E-09	1.15E-08	1.57E-07
235	1.40E-08	1.01E-09	6.62E-09	1.08E-07
236	9.85E-09	8.27E-10	5.73E-09	9.59E-08
237	8.64E-09	7.59E-10	5.40E-09	9.15E-08
238	8.69E-09	7.85E-10	5.53E-09	9.32E-08
239	3.17E-08	2.15E-09	1.19E-08	1.62E-07
240	1.80E-08	1.44E-09	8.63E-09	1.29E-07
241	2.78E-09	2.14E-10	2.75E-09	2.45E-08
242	2.33E-08	2.00E-09	1.12E-08	1.54E-07
243	2.79E-08	2.39E-09	1.30E-08	1.76E-07
244	6.79E-08	4.63E-09	2.30E-08	2.58E-07
245	7.19E-09	7.41E-10	5.31E-09	9.04E-08
246	6.59E-09	6.96E-10	5.09E-09	8.74E-08
247	2.10E-08	1.81E-09	1.04E-08	1.47E-07
248	3.50E-09	3.68E-10	3.50E-09	3.43E-08
249	1.68E-08	2.06E-09	1.15E-08	1.57E-07
250	2.56E-08	2.85E-09	1.50E-08	1.88E-07
251	2.48E-08	8.20E-10	5.61E-09	8.92E-08
252	3.03E-08	1.99E-09	1.12E-08	1.55E-07
253	3.10E-08	2.32E-09	1.27E-08	1.73E-07
254	3.03E-08	2.31E-09	1.27E-08	1.72E-07
255	1.98E-08	1.59E-09	9.32E-09	1.35E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
256	7.33E-08	5.15E-09	2.54E-08	2.85E-07
257	1.64E-08	3.76E-09	1.90E-08	2.18E-07
258	3.29E-08	9.32E-10	6.08E-09	9.16E-08
259	1.63E-08	6.46E-10	4.79E-09	8.01E-08
260	3.41E-08	9.62E-10	6.22E-09	9.32E-08
261	3.02E-08	9.33E-10	6.08E-09	9.18E-08
262	3.33E-08	1.02E-09	6.46E-09	9.59E-08
263	2.97E-08	9.32E-10	6.08E-09	9.19E-08
264	3.59E-08	1.11E-09	6.90E-09	1.01E-07
265	2.96E-08	9.33E-10	6.08E-09	9.19E-08
266	3.09E-08	1.06E-09	6.68E-09	9.83E-08
267	1.95E-08	9.22E-10	6.04E-09	9.19E-08
268	3.94E-08	2.29E-09	1.26E-08	1.72E-07
269	3.65E-08	2.25E-09	1.25E-08	1.70E-07
270	2.08E-08	1.09E-09	6.80E-09	1.00E-07
271	5.73E-08	3.05E-09	1.60E-08	2.01E-07
272	2.26E-08	1.54E-09	9.11E-09	1.33E-07
273	4.90E-08	2.89E-09	1.52E-08	1.92E-07
274	3.00E-09	2.24E-10	2.80E-09	2.54E-08
275	2.17E-08	1.46E-09	8.74E-09	1.30E-07
276	5.37E-08	3.03E-09	1.59E-08	2.00E-07
277	1.05E-08	8.44E-10	5.83E-09	9.81E-08
278	5.24E-08	3.02E-09	1.59E-08	1.99E-07
279	5.55E-08	3.47E-09	1.80E-08	2.22E-07
280	3.18E-09	2.48E-10	2.92E-09	2.75E-08
281	1.67E-08	1.21E-09	7.57E-09	1.17E-07
282	5.11E-08	3.01E-09	1.58E-08	1.99E-07
283	2.94E-09	2.21E-10	2.78E-09	2.51E-08
284	2.71E-08	1.96E-09	1.11E-08	1.54E-07
285	5.00E-08	3.00E-09	1.58E-08	1.98E-07
286	5.52E-08	3.31E-09	1.72E-08	2.14E-07
287	4.81E-08	3.13E-09	1.64E-08	2.05E-07
288	5.30E-08	3.45E-09	1.79E-08	2.21E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
289	5.52E-08	3.59E-09	1.85E-08	2.28E-07
290	1.58E-08	1.19E-09	7.48E-09	1.16E-07
291	4.86E-08	2.99E-09	1.57E-08	1.98E-07
292	7.91E-08	4.34E-09	2.17E-08	2.48E-07
293	6.95E-08	4.16E-09	2.09E-08	2.39E-07
294	9.40E-09	7.55E-10	5.40E-09	9.23E-08
295	4.72E-08	2.98E-09	1.57E-08	1.97E-07
296	4.12E-08	2.81E-09	1.49E-08	1.88E-07
297	9.04E-09	7.46E-10	5.35E-09	9.16E-08
298	7.98E-09	6.86E-10	5.06E-09	8.76E-08
299	4.64E-08	2.97E-09	1.56E-08	1.97E-07
300	5.27E-08	3.54E-09	1.83E-08	2.26E-07
301	1.57E-08	1.34E-09	8.20E-09	1.25E-07
302	2.79E-08	2.19E-09	1.22E-08	1.67E-07
303	2.02E-08	1.69E-09	9.77E-09	1.39E-07
304	2.42E-08	2.04E-09	1.14E-08	1.58E-07
305	4.04E-08	2.90E-09	1.53E-08	1.93E-07
306	4.91E-08	3.52E-09	1.82E-08	2.25E-07
307	8.14E-08	5.22E-09	2.57E-08	2.89E-07
308	6.64E-08	4.28E-09	2.14E-08	2.45E-07
309	2.79E-09	2.10E-10	2.73E-09	2.43E-08
310	7.65E-09	6.94E-10	5.09E-09	8.82E-08
311	1.73E-08	1.40E-09	8.45E-09	1.26E-07
312	1.55E-08	1.32E-09	8.08E-09	1.22E-07
313	1.98E-08	1.58E-09	9.27E-09	1.35E-07
314	1.77E-08	1.49E-09	8.86E-09	1.30E-07
315	1.92E-08	1.67E-09	9.65E-09	1.37E-07
316	3.94E-08	2.89E-09	1.52E-08	1.93E-07
317	1.12E-07	6.89E-09	3.27E-08	3.32E-07
318	3.30E-08	2.70E-09	1.43E-08	1.83E-07
319	3.18E-08	2.76E-09	1.46E-08	1.86E-07
320	3.17E-08	2.76E-09	1.46E-08	1.86E-07
321	3.39E-08	1.85E-09	1.01E-08	1.24E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
322	2.71E-08	2.57E-09	1.38E-08	1.76E-07
323	2.98E-08	2.72E-09	1.44E-08	1.84E-07
324	2.68E-09	2.01E-10	2.68E-09	2.34E-08
325	2.95E-08	2.71E-09	1.44E-08	1.84E-07
326	6.82E-08	4.57E-09	2.28E-08	2.60E-07
327	1.05E-07	6.84E-09	3.24E-08	3.27E-07
328	2.71E-08	2.66E-09	1.41E-08	1.81E-07
329	2.65E-09	1.98E-10	2.66E-09	2.32E-08
330	2.60E-08	2.63E-09	1.40E-08	1.79E-07
331	3.14E-08	3.20E-09	1.67E-08	2.08E-07
332	6.06E-08	4.50E-09	2.25E-08	2.57E-07
333	6.70E-08	4.98E-09	2.47E-08	2.79E-07
334	5.41E-08	4.96E-09	2.45E-08	2.77E-07
335	4.34E-08	4.26E-09	2.13E-08	2.44E-07
336	1.07E-07	6.75E-09	3.21E-08	3.28E-07
337	5.59E-09	6.22E-10	4.74E-09	8.33E-08
338	8.88E-09	1.04E-09	6.70E-09	1.05E-07
339	2.58E-08	2.63E-09	1.40E-08	1.79E-07
340	5.88E-08	5.07E-09	2.51E-08	2.82E-07
341	4.38E-08	2.51E-09	1.29E-08	1.43E-07
342	2.09E-08	2.47E-09	1.33E-08	1.71E-07
343	5.93E-08	5.32E-09	2.62E-08	2.95E-07
344	5.23E-08	4.80E-09	2.38E-08	2.70E-07
345	3.89E-09	4.58E-10	3.93E-09	7.24E-08
346	6.00E-09	7.95E-10	5.54E-09	9.14E-08
347	8.36E-09	1.12E-09	7.11E-09	1.10E-07
348	7.14E-09	9.67E-10	6.35E-09	1.00E-07
349	1.35E-08	1.62E-09	9.46E-09	1.35E-07
350	1.04E-08	1.51E-09	8.88E-09	1.28E-07
351	8.92E-09	1.26E-09	7.69E-09	1.14E-07
352	2.99E-08	3.34E-09	1.74E-08	2.16E-07
353	2.49E-08	2.75E-09	1.46E-08	1.86E-07
354	2.00E-08	2.49E-09	1.34E-08	1.72E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
355	1.98E-08	2.60E-09	1.39E-08	1.77E-07
356	5.23E-08	5.21E-09	2.57E-08	2.89E-07
357	4.30E-08	4.27E-09	2.14E-08	2.45E-07
358	4.30E-08	4.27E-09	2.14E-08	2.46E-07
359	4.73E-08	4.71E-09	2.34E-08	2.66E-07
360	5.22E-08	5.21E-09	2.57E-08	2.89E-07
361	3.17E-08	3.80E-09	1.92E-08	2.23E-07
362	2.82E-08	3.59E-09	1.82E-08	2.13E-07
363	1.06E-07	8.15E-09	3.80E-08	3.66E-07
364	1.04E-08	1.50E-09	8.87E-09	1.28E-07
365	5.23E-08	5.21E-09	2.57E-08	2.89E-07
366	9.96E-09	1.52E-09	8.97E-09	1.29E-07
367	1.53E-08	2.24E-09	1.22E-08	1.59E-07
368	1.66E-08	2.46E-09	1.32E-08	1.70E-07
369	1.36E-08	2.08E-09	1.15E-08	1.50E-07
370	1.48E-08	2.29E-09	1.25E-08	1.61E-07
371	3.47E-09	4.26E-10	3.78E-09	7.02E-08
372	2.27E-08	3.50E-09	1.78E-08	2.08E-07
373	6.62E-09	9.85E-10	6.44E-09	1.02E-07
374	2.44E-08	3.64E-09	1.84E-08	2.15E-07
375	2.95E-08	4.25E-09	2.13E-08	2.44E-07
376	3.74E-08	5.46E-09	2.68E-08	3.00E-07
377	2.85E-08	4.21E-09	2.11E-08	2.42E-07
378	1.67E-08	3.20E-09	1.64E-08	1.94E-07
379	1.08E-08	2.75E-09	1.44E-08	1.72E-07
380	1.20E-08	3.03E-09	1.57E-08	1.86E-07
381	1.07E-08	3.15E-09	1.62E-08	1.90E-07
382	4.26E-08	1.17E-09	7.14E-09	9.16E-08
383	3.94E-08	1.17E-09	7.17E-09	9.21E-08
384	4.18E-08	1.36E-09	8.04E-09	1.01E-07
385	3.87E-08	1.17E-09	7.18E-09	9.22E-08
386	4.26E-08	1.28E-09	7.68E-09	9.72E-08
387	3.92E-09	2.45E-10	2.95E-09	1.97E-08

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
388	8.12E-08	4.41E-09	2.21E-08	2.46E-07
389	2.98E-09	2.11E-10	2.77E-09	1.66E-08
390	3.03E-09	2.16E-10	2.80E-09	1.71E-08
391	7.30E-08	4.12E-09	2.08E-08	2.32E-07
392	6.43E-08	3.95E-09	2.00E-08	2.24E-07
393	2.90E-08	2.09E-09	1.17E-08	1.55E-07
394	5.13E-08	3.37E-09	1.76E-08	2.11E-07
395	6.99E-08	4.11E-09	2.07E-08	2.32E-07
396	7.72E-08	4.53E-09	2.27E-08	2.52E-07
397	2.28E-08	1.70E-09	9.88E-09	1.33E-07
398	6.80E-08	4.09E-09	2.07E-08	2.31E-07
399	6.64E-08	4.09E-09	2.06E-08	2.31E-07
400	6.97E-08	4.90E-09	2.44E-08	2.69E-07
401	2.02E-08	1.68E-09	9.76E-09	1.31E-07
402	5.13E-08	4.19E-09	2.11E-08	2.36E-07
403	1.89E-08	2.20E-09	1.21E-08	1.50E-07
404	2.07E-08	2.42E-09	1.31E-08	1.62E-07
405	5.63E-08	4.62E-09	2.31E-08	2.57E-07
406	3.60E-08	3.92E-09	1.99E-08	2.23E-07
407	3.96E-08	4.33E-09	2.18E-08	2.43E-07
408	3.21E-08	4.21E-09	2.12E-08	2.36E-07
409	2.65E-08	3.46E-09	1.77E-08	2.01E-07
410	9.23E-09	1.40E-09	8.40E-09	1.14E-07
411	2.44E-08	2.97E-09	1.57E-08	1.91E-07
412	4.36E-08	4.77E-09	2.38E-08	2.64E-07
413	5.85E-08	6.44E-09	3.15E-08	3.43E-07
414	2.92E-08	3.60E-09	1.84E-08	2.08E-07
415	2.66E-08	3.46E-09	1.77E-08	2.01E-07
416	2.66E-08	3.46E-09	1.78E-08	2.01E-07
417	2.92E-08	3.82E-09	1.94E-08	2.18E-07
418	3.21E-08	4.21E-09	2.12E-08	2.36E-07
419	2.85E-08	3.97E-09	2.01E-08	2.25E-07
420	2.29E-08	3.32E-09	1.71E-08	1.94E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
421	1.37E-08	2.17E-09	1.19E-08	1.48E-07
422	1.86E-08	3.13E-09	1.62E-08	1.85E-07
423	4.30E-08	6.01E-09	2.89E-08	2.92E-07
424	3.91E-08	1.15E-09	7.04E-09	2.42E-07
425	3.63E-08	1.15E-09	7.07E-09	2.42E-07
426	3.29E-08	1.13E-09	6.97E-09	2.41E-07
427	4.75E-08	1.53E-09	8.68E-09	2.53E-07
428	1.21E-08	5.42E-10	4.32E-09	2.18E-07
429	3.57E-08	1.15E-09	7.08E-09	2.42E-07
430	3.93E-08	1.35E-09	8.00E-09	2.52E-07
431	3.60E-09	2.39E-10	2.88E-09	1.68E-07
432	3.46E-08	1.16E-09	7.08E-09	2.42E-07
433	8.92E-08	4.02E-09	2.03E-08	3.81E-07
434	8.88E-08	4.02E-09	2.04E-08	3.81E-07
435	8.61E-08	4.01E-09	2.03E-08	3.81E-07
436	7.92E-08	4.54E-09	2.28E-08	4.07E-07
437	8.40E-08	4.71E-09	2.36E-08	4.15E-07
438	7.40E-08	4.51E-09	2.26E-08	4.05E-07
439	7.20E-08	3.96E-09	2.01E-08	3.79E-07
440	7.06E-08	3.95E-09	2.00E-08	3.78E-07
441	6.61E-08	3.93E-09	2.00E-08	3.77E-07
442	8.06E-08	4.78E-09	2.39E-08	4.19E-07
443	6.42E-08	4.43E-09	2.23E-08	4.01E-07
444	6.45E-08	3.92E-09	1.99E-08	3.77E-07
445	4.52E-08	3.13E-09	1.65E-08	3.52E-07
446	6.32E-08	3.91E-09	1.99E-08	3.76E-07
447	3.26E-08	2.46E-09	1.33E-08	3.16E-07
448	6.13E-08	3.89E-09	1.98E-08	3.75E-07
449	5.55E-08	3.77E-09	1.92E-08	3.70E-07
450	6.58E-08	4.58E-09	2.29E-08	4.08E-07
451	4.32E-08	2.77E-09	1.48E-08	3.34E-07
452	5.87E-08	3.87E-09	1.97E-08	3.75E-07
453	6.45E-08	4.57E-09	2.29E-08	4.08E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
454	1.40E-08	1.23E-09	7.65E-09	2.59E-07
455	5.00E-08	3.71E-09	1.89E-08	3.67E-07
456	7.13E-08	4.31E-09	2.17E-08	3.94E-07
457	3.68E-08	2.99E-09	1.58E-08	3.45E-07
458	6.37E-08	4.64E-09	2.32E-08	4.12E-07
459	5.07E-08	3.79E-09	1.93E-08	3.71E-07
460	1.25E-08	1.18E-09	7.40E-09	2.56E-07
461	2.29E-08	2.18E-09	1.20E-08	3.01E-07
462	4.99E-08	3.78E-09	1.92E-08	3.70E-07
463	4.52E-08	3.65E-09	1.86E-08	3.64E-07
464	8.06E-08	6.00E-09	2.88E-08	4.42E-07
465	9.87E-09	1.08E-09	6.90E-09	2.50E-07
466	4.02E-08	3.64E-09	1.86E-08	3.63E-07
467	5.58E-08	4.66E-09	2.34E-08	4.13E-07
468	3.75E-08	3.58E-09	1.83E-08	3.60E-07
469	3.71E-08	3.57E-09	1.83E-08	3.60E-07
470	3.45E-08	3.52E-09	1.80E-08	3.57E-07
471	1.87E-07	1.08E-08	4.83E-08	8.41E-07
472	3.31E-08	3.49E-09	1.79E-08	3.55E-07
473	5.37E-08	5.72E-09	2.83E-08	4.64E-07
474	6.89E-08	6.18E-09	2.96E-08	4.50E-07
475	1.39E-07	9.12E-09	4.20E-08	8.10E-07
476	9.87E-08	8.77E-09	4.04E-08	7.95E-07
477	1.21E-07	1.08E-08	4.91E-08	8.69E-07
478	1.17E-08	1.45E-09	8.68E-09	2.69E-07
479	2.02E-08	2.35E-09	1.28E-08	3.10E-07
480	1.49E-08	1.90E-09	1.07E-08	2.86E-07
481	3.29E-08	3.48E-09	1.79E-08	3.55E-07
482	3.95E-08	4.20E-09	2.12E-08	3.90E-07
483	3.29E-08	3.69E-09	1.88E-08	3.65E-07
484	5.64E-08	5.82E-09	2.80E-08	4.34E-07
485	1.24E-07	8.78E-09	4.09E-08	5.38E-07
486	2.89E-08	3.38E-09	1.74E-08	3.50E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
487	1.21E-07	9.21E-09	4.24E-08	8.14E-07
488	2.67E-08	3.31E-09	1.71E-08	3.47E-07
489	2.50E-08	3.25E-09	1.68E-08	3.44E-07
490	3.42E-08	4.23E-09	2.13E-08	3.92E-07
491	2.83E-08	3.47E-09	1.78E-08	3.55E-07
492	3.11E-08	3.82E-09	1.95E-08	3.72E-07
493	3.42E-08	4.22E-09	2.13E-08	3.91E-07
494	2.31E-08	3.19E-09	1.65E-08	3.40E-07
495	2.11E-08	3.05E-09	1.58E-08	3.33E-07
496	2.30E-08	3.36E-09	1.73E-08	3.48E-07
497	6.69E-08	6.95E-09	3.32E-08	4.83E-07
498	5.04E-08	5.97E-09	2.87E-08	4.41E-07
499	1.06E-07	9.28E-09	4.27E-08	8.16E-07
500	1.17E-07	1.03E-08	4.71E-08	8.54E-07
501	2.53E-08	3.71E-09	1.89E-08	3.65E-07
502	2.26E-08	3.49E-09	1.79E-08	3.54E-07
503	1.29E-07	1.14E-08	5.19E-08	8.95E-07
504	1.98E-08	3.05E-09	1.58E-08	3.33E-07
505	1.81E-08	2.91E-09	1.52E-08	3.26E-07
506	9.34E-08	9.29E-09	4.28E-08	8.17E-07
507	1.94E-08	3.19E-09	1.65E-08	3.40E-07
508	4.72E-08	6.99E-09	3.30E-08	4.70E-07
509	7.90E-08	9.30E-09	4.28E-08	8.17E-07
510	1.56E-08	3.04E-09	1.58E-08	3.32E-07
511	1.40E-08	2.74E-09	1.44E-08	3.18E-07
512	1.67E-08	2.99E-09	1.56E-08	3.31E-07
513	6.60E-08	2.58E-09	1.39E-08	3.27E-07
514	2.92E-08	1.08E-09	6.76E-09	2.40E-07
515	4.79E-08	1.51E-09	8.60E-09	2.54E-07
516	8.19E-08	2.33E-09	1.19E-08	5.47E-07
517	6.48E-08	2.57E-09	1.39E-08	3.27E-07
518	7.91E-08	3.12E-09	1.65E-08	3.57E-07
519	1.02E-07	4.27E-09	2.16E-08	3.99E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
520	4.73E-08	1.51E-09	8.62E-09	2.54E-07
521	5.02E-08	1.57E-09	8.87E-09	2.56E-07
522	5.81E-08	2.49E-09	1.35E-08	3.23E-07
523	4.72E-08	1.51E-09	8.62E-09	2.54E-07
524	4.34E-08	1.50E-09	8.57E-09	2.53E-07
525	7.01E-08	2.03E-09	1.07E-08	5.43E-07
526	1.24E-07	5.57E-09	2.71E-08	4.34E-07
527	1.21E-07	5.58E-09	2.72E-08	4.35E-07
528	4.52E-08	2.85E-09	1.53E-08	3.43E-07
529	1.28E-07	6.71E-09	3.23E-08	4.85E-07
530	3.44E-08	2.31E-09	1.27E-08	3.13E-07
531	5.22E-08	3.64E-09	1.87E-08	3.68E-07
532	1.16E-07	5.89E-09	2.85E-08	4.44E-07
533	1.72E-07	7.24E-09	3.42E-08	4.84E-07
534	1.00E-07	5.59E-09	2.72E-08	4.35E-07
535	3.85E-08	3.12E-09	1.65E-08	3.57E-07
536	2.78E-08	2.19E-09	1.21E-08	3.06E-07
537	3.05E-08	2.41E-09	1.31E-08	3.18E-07
538	3.36E-08	2.66E-09	1.43E-08	3.31E-07
539	4.29E-08	3.51E-09	1.81E-08	3.61E-07
540	1.00E-07	6.16E-09	2.98E-08	4.61E-07
541	9.05E-08	6.46E-09	3.12E-08	4.74E-07
542	1.66E-07	1.00E-08	4.62E-08	8.53E-07
543	2.69E-08	2.17E-09	1.20E-08	3.05E-07
544	8.84E-08	5.57E-09	2.71E-08	4.35E-07
545	9.70E-08	6.15E-09	2.98E-08	4.60E-07
546	5.04E-08	4.02E-09	2.05E-08	3.87E-07
547	8.48E-08	5.56E-09	2.71E-08	4.34E-07
548	4.40E-08	3.91E-09	1.99E-08	3.81E-07
549	3.80E-08	3.50E-09	1.81E-08	3.61E-07
550	3.06E-08	3.01E-09	1.57E-08	3.36E-07
551	7.32E-08	5.50E-09	2.68E-08	4.32E-07
552	1.31E-07	9.20E-09	4.22E-08	8.08E-07

Pipeline	Methane Failure Rates (per m per year) for V3.04 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
553	1.69E-08	1.89E-09	1.07E-08	2.89E-07
554	8.45E-08	8.02E-09	3.78E-08	5.20E-07
555	1.68E-08	1.89E-09	1.07E-08	2.89E-07
556	6.01E-08	5.39E-09	2.63E-08	4.26E-07
557	5.02E-08	5.27E-09	2.57E-08	4.21E-07
558	4.60E-08	5.12E-09	2.50E-08	4.14E-07
559	1.15E-07	8.79E-09	4.07E-08	8.06E-07
560	1.34E-07	9.69E-09	4.44E-08	8.28E-07
561	1.48E-07	1.08E-08	4.90E-08	8.66E-07
562	1.55E-07	1.07E-08	4.81E-08	8.47E-07
563	2.10E-07	1.44E-08	6.46E-08	9.83E-07
564	5.00E-08	5.26E-09	2.57E-08	4.20E-07
565	1.00E-07	8.28E-09	3.89E-08	5.27E-07
566	1.72E-08	2.68E-09	1.42E-08	3.19E-07
567	4.34E-08	5.30E-09	2.59E-08	4.22E-07
568	4.78E-08	5.85E-09	2.84E-08	4.47E-07
569	5.27E-08	6.47E-09	3.12E-08	4.74E-07
570	1.07E-07	1.09E-08	4.98E-08	8.85E-07
571	1.79E-08	2.80E-09	1.48E-08	3.25E-07
572	5.88E-09	1.75E-09	9.86E-09	2.71E-07
573	9.15E-08	3.34E-09	1.75E-08	6.64E-07
574	6.93E-08	1.93E-09	1.04E-08	8.43E-07
575	1.20E-07	4.14E-09	2.10E-08	6.93E-07
576	6.85E-08	1.93E-09	1.04E-08	8.43E-07
577	1.91E-07	7.61E-09	3.58E-08	1.07E-06
578	8.27E-08	4.89E-09	2.45E-08	7.31E-07
579	1.63E-08	1.64E-09	9.60E-09	5.80E-07
580	1.95E-08	3.51E-09	1.80E-08	6.58E-07
581	1.64E-08	2.88E-09	1.51E-08	6.27E-07
582	1.79E-08	3.18E-09	1.65E-08	6.42E-07
583	1.40E-08	2.92E-09	1.53E-08	6.28E-07
584	9.63E-08	7.83E-09	3.79E-08	8.61E-07

13.2 V3.1 of PIPIN

Table 16 Methane failure rates using V3.1 of PIPIN

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
1	2.56E-09	1.72E-10	2.53E-09	2.1E-08
2	2.67E-09	1.77E-10	2.56E-09	2.14E-08
3	2.79E-09	1.82E-10	2.58E-09	2.18E-08
4	3.02E-09	1.90E-10	2.62E-09	2.24E-08
5	2.78E-09	1.81E-10	2.58E-09	2.18E-08
6	2.72E-09	1.80E-10	2.57E-09	2.16E-08
7	3.38E-09	2.01E-10	2.68E-09	2.33E-08
8	3.38E-09	2.11E-10	2.73E-09	2.38E-08
9	2.55E-09	1.74E-10	2.54E-09	2.12E-08
10	3.89E-09	2.09E-10	2.72E-09	2.39E-08
11	3.49E-09	2.01E-10	2.68E-09	2.33E-08
12	3.22E-09	1.95E-10	2.65E-09	2.28E-08
13	3.06E-09	1.91E-10	2.63E-09	2.25E-08
14	2.53E-09	1.72E-10	2.53E-09	2.10E-08
15	2.84E-09	2.05E-10	2.70E-09	2.37E-08
16	3.27E-09	2.61E-10	2.98E-09	2.76E-08
17	5.46E-09	2.45E-10	2.90E-09	2.63E-08
18	2.73E-09	1.79E-10	2.57E-09	2.16E-08
19	4.21E-09	2.23E-10	2.79E-09	2.47E-08
20	4.39E-09	2.29E-10	2.82E-09	2.51E-08
21	4.59E-09	2.35E-10	2.85E-09	2.56E-08
22	3.84E-09	2.15E-10	2.75E-09	2.41E-08
23	2.72E-09	1.79E-10	2.57E-09	2.16E-08
24	2.65E-09	1.76E-10	2.55E-09	2.14E-08
25	2.67E-09	1.77E-10	2.56E-09	2.14E-08
26	2.68E-09	1.78E-10	2.56E-09	2.15E-08
27	2.93E-09	1.87E-10	2.61E-09	2.22E-08
28	3.82E-09	2.16E-10	2.75E-09	2.42E-08
29	3.82E-09	2.16E-10	2.75E-09	2.42E-08
30	4.12E-09	2.26E-10	2.80E-09	2.50E-08
31	4.12E-09	2.26E-10	2.80E-09	2.50E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
32	4.12E-09	2.26E-10	2.80E-09	2.50E-08
33	4.12E-09	2.26E-10	2.80E-09	2.50E-08
34	2.58E-09	1.74E-10	2.54E-09	2.12E-08
35	2.93E-09	1.98E-10	2.66E-09	2.29E-08
36	2.81E-09	1.95E-10	2.65E-09	2.27E-08
37	2.84E-09	1.97E-10	2.66E-09	2.29E-08
38	3.33E-09	2.56E-10	2.95E-09	2.73E-08
39	6.68E-09	4.78E-10	3.98E-09	7.05E-08
40	3.04E-09	2.42E-10	2.88E-09	2.63E-08
41	3.82E-09	2.13E-10	2.74E-09	2.41E-08
42	3.97E-09	2.18E-10	2.76E-09	2.45E-08
43	6.00E-09	2.63E-10	2.99E-09	2.74E-08
44	4.37E-09	2.31E-10	2.82E-09	2.52E-08
45	2.71E-09	1.78E-10	2.56E-09	2.16E-08
46	3.63E-09	2.11E-10	2.73E-09	2.39E-08
47	3.88E-09	2.20E-10	2.77E-09	2.46E-08
48	3.88E-09	2.20E-10	2.77E-09	2.46E-08
49	5.37E-09	2.55E-10	2.95E-09	2.69E-08
50	5.67E-09	2.64E-10	2.99E-09	2.75E-08
51	6.02E-09	2.74E-10	3.04E-09	2.83E-08
52	4.44E-09	2.35E-10	2.85E-09	2.55E-08
53	2.76E-09	1.90E-10	2.63E-09	2.27E-08
54	2.72E-09	1.88E-10	2.62E-09	2.26E-08
55	3.00E-09	2.05E-10	2.70E-09	2.35E-08
56	3.36E-09	2.27E-10	2.81E-09	2.50E-08
57	2.70E-09	1.88E-10	2.61E-09	2.25E-08
58	2.73E-09	1.90E-10	2.63E-09	2.27E-08
59	2.75E-09	1.92E-10	2.64E-09	2.29E-08
60	3.90E-09	2.83E-10	3.09E-09	2.96E-08
61	4.05E-09	2.95E-10	3.15E-09	3.06E-08
62	4.05E-09	2.95E-10	3.16E-09	3.06E-08
63	3.31E-09	2.26E-10	2.80E-09	2.49E-08
64	3.40E-09	2.32E-10	2.83E-09	2.54E-08
65	3.06E-09	2.18E-10	2.77E-09	2.50E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
66	2.62E-09	1.83E-10	2.59E-09	2.20E-08
67	3.67E-09	2.79E-10	3.07E-09	2.93E-08
68	3.94E-09	3.05E-10	3.20E-09	3.13E-08
69	3.57E-09	2.72E-10	3.04E-09	2.88E-08
70	3.51E-09	2.70E-10	3.03E-09	2.86E-08
71	4.73E-09	3.65E-10	3.50E-09	3.51E-08
72	6.17E-09	6.03E-10	4.65E-09	4.99E-08
73	7.49E-09	8.34E-10	5.73E-09	9.39E-08
74	2.77E-09	2.44E-10	2.89E-09	2.62E-08
75	5.09E-09	2.54E-10	2.95E-09	2.71E-08
76	1.36E-08	4.44E-10	3.84E-09	6.99E-08
77	2.87E-09	1.86E-10	2.60E-09	2.22E-08
78	4.74E-09	2.50E-10	2.92E-09	2.68E-08
79	4.33E-09	2.36E-10	2.85E-09	2.57E-08
80	4.52E-09	2.42E-10	2.88E-09	2.62E-08
81	4.74E-09	2.50E-10	2.92E-09	2.68E-08
82	1.2E-08	4.31E-10	3.78E-09	6.93E-08
83	1.42E-08	4.91E-10	4.07E-09	7.28E-08
84	1.18E-08	4.29E-10	3.77E-09	6.92E-08
85	1.17E-08	4.29E-10	3.77E-09	6.91E-08
86	7.72E-09	4.00E-10	3.63E-09	6.77E-08
87	3.16E-09	2.17E-10	2.76E-09	2.50E-08
88	3.23E-09	2.22E-10	2.79E-09	2.54E-08
89	3.09E-09	2.06E-10	2.71E-09	2.37E-08
90	7.44E-09	3.97E-10	3.62E-09	6.76E-08
91	5.05E-09	3.45E-10	3.40E-09	3.40E-08
92	4.02E-09	2.85E-10	3.11E-09	3.00E-08
93	3.38E-09	2.27E-10	2.80E-09	2.51E-08
94	5.22E-09	3.63E-10	3.49E-09	3.53E-08
95	5.49E-09	3.83E-10	3.59E-09	3.68E-08
96	5.5E-09	3.83E-10	3.59E-09	3.68E-08
97	6.44E-09	3.88E-10	3.58E-09	6.71E-08
98	4.96E-09	3.56E-10	3.46E-09	3.48E-08
99	6.11E-09	3.84E-10	3.56E-09	6.68E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
100	5.16E-09	3.75E-10	3.55E-09	3.62E-08
101	4.79E-09	3.51E-10	3.43E-09	3.44E-08
102	2.65E-09	1.84E-10	2.60E-09	2.22E-08
103	2.68E-09	1.87E-10	2.61E-09	2.25E-08
104	2.94E-09	2.11E-10	2.73E-09	2.45E-08
105	3.01E-09	2.19E-10	2.77E-09	2.52E-08
106	3.87E-09	2.88E-10	3.12E-09	3.02E-08
107	4.02E-09	3.01E-10	3.19E-09	3.13E-08
108	4.73E-09	3.50E-10	3.43E-09	3.43E-08
109	4.95E-09	3.68E-10	3.52E-09	3.57E-08
110	5.43E-09	4.07E-10	3.71E-09	3.86E-08
111	6.20E-09	4.03E-10	3.65E-09	6.80E-08
112	2.66E-09	1.85E-10	2.60E-09	2.23E-08
113	3.97E-09	2.91E-10	3.13E-09	3.05E-08
114	4.28E-09	3.17E-10	3.27E-09	3.25E-08
115	4.30E-09	3.18E-10	3.27E-09	3.27E-08
116	4.49E-09	3.35E-10	3.36E-09	3.40E-08
117	4.94E-09	3.72E-10	3.55E-09	3.69E-08
118	4.64E-09	3.47E-10	3.41E-09	3.41E-08
119	5.72E-09	3.78E-10	3.53E-09	6.65E-08
120	6.44E-09	4.26E-10	3.76E-09	6.94E-08
121	3.95E-09	2.90E-10	3.13E-09	3.04E-08
122	4.60E-09	3.46E-10	3.40E-09	3.40E-08
123	4.83E-09	3.64E-10	3.50E-09	3.54E-08
124	3.72E-09	2.89E-10	3.13E-09	3.03E-08
125	4.72E-09	3.73E-10	3.54E-09	3.60E-08
126	5.95E-09	4.16E-10	3.71E-09	6.88E-08
127	5.24E-09	3.70E-10	3.49E-09	6.6E-08
128	3.42E-09	2.64E-10	3.00E-09	2.83E-08
129	3.62E-09	2.85E-10	3.10E-09	3.00E-08
130	1.27E-08	9.43E-10	6.27E-09	1.01E-07
131	1.68E-08	9.01E-10	5.96E-09	9.20E-08
132	6.95E-09	5.48E-10	4.40E-09	4.75E-08
133	4.10E-09	3.28E-10	3.32E-09	3.27E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
134	1.22E-08	9.31E-10	6.21E-09	1.01E-07
135	3.63E-09	3.06E-10	3.20E-09	3.1E-08
136	2.63E-09	1.89E-10	2.62E-09	2.25E-08
137	1.05E-08	9.25E-10	6.18E-09	1.00E-07
138	1.22E-08	1.09E-09	6.98E-09	1.10E-07
139	9.21E-09	8.50E-10	5.82E-09	9.57E-08
140	1.07E-08	1.04E-09	6.73E-09	1.07E-07
141	8.18E-09	8.14E-10	5.65E-09	9.34E-08
142	2.52E-09	1.71E-10	2.53E-09	2.09E-08
143	2.54E-09	1.74E-10	2.54E-09	2.12E-08
144	2.58E-09	1.85E-10	2.60E-09	2.21E-08
145	6.43E-09	7.69E-10	5.43E-09	9.06E-08
146	2.52E-09	1.71E-10	2.53E-09	2.09E-08
147	2.63E-09	2.05E-10	2.70E-09	2.36E-08
148	2.68E-09	2.23E-10	2.79E-09	2.50E-08
149	2.74E-09	2.36E-10	2.85E-09	2.57E-08
150	2.78E-09	2.49E-10	2.92E-09	2.67E-08
151	6.22E-09	2.98E-10	3.16E-09	2.99E-08
152	6.67E-09	5.13E-10	4.23E-09	4.55E-08
153	6.55E-09	5.09E-10	4.21E-09	4.52E-08
154	1.48E-08	1.10E-09	7.05E-09	1.12E-07
155	5.80E-09	4.83E-10	4.08E-09	4.33E-08
156	7.36E-09	8.14E-10	5.65E-09	9.42E-08
157	5.58E-09	7.30E-10	5.25E-09	8.87E-08
158	4.17E-09	2.27E-10	2.81E-09	2.52E-08
159	2.80E-09	1.87E-10	2.61E-09	2.25E-08
160	3.68E-09	2.22E-10	2.78E-09	2.48E-08
161	3.81E-09	2.27E-10	2.81E-09	2.52E-08
162	3.95E-09	2.33E-10	2.84E-09	2.57E-08
163	6.09E-09	3.05E-10	3.19E-09	2.99E-08
164	8.76E-09	3.86E-10	3.57E-09	6.72E-08
165	9.43E-09	4.09E-10	3.68E-09	6.86E-08
166	1.02E-08	4.35E-10	3.81E-09	7.03E-08
167	3.78E-09	2.27E-10	2.81E-09	2.52E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
168	3.91E-09	2.33E-10	2.84E-09	2.57E-08
169	8.63E-09	3.85E-10	3.57E-09	6.72E-08
170	9.29E-09	4.09E-10	3.68E-09	6.86E-08
171	1.00E-08	4.34E-10	3.81E-09	7.02E-08
172	8.60E-09	3.85E-10	3.57E-09	6.72E-08
173	6.12E-09	3.65E-10	3.47E-09	6.60E-08
174	9.93E-09	6.59E-10	4.94E-09	5.40E-08
175	9.51E-09	6.40E-10	4.84E-09	5.28E-08
176	1.03E-08	6.92E-10	5.10E-09	5.64E-08
177	1.31E-08	8.78E-10	5.97E-09	9.85E-08
178	9.40E-09	5.20E-10	4.21E-09	7.42E-08
179	8.14E-09	5.88E-10	4.58E-09	4.92E-08
180	4.32E-09	3.37E-10	3.36E-09	3.37E-08
181	1.20E-08	8.56E-10	5.87E-09	9.72E-08
182	1.41E-08	1.01E-09	6.63E-09	1.07E-07
183	3.88E-09	3.01E-10	3.19E-09	3.10E-08
184	4.18E-09	3.31E-10	3.33E-09	3.33E-08
185	8.92E-09	6.60E-10	4.94E-09	5.42E-08
186	7.81E-09	6.08E-10	4.68E-09	5.06E-08
187	1.24E-08	9.19E-10	6.17E-09	1.01E-07
188	1.34E-08	9.98E-10	6.56E-09	1.06E-07
189	9.33E-09	7.05E-10	5.17E-09	5.73E-08
190	8.05E-09	6.05E-10	4.67E-09	5.05E-08
191	1.28E-08	9.05E-10	6.11E-09	1.00E-07
192	3.94E-09	3.12E-10	3.24E-09	3.18E-08
193	1.06E-08	8.25E-10	5.71E-09	9.52E-08
194	1.15E-08	8.95E-10	6.06E-09	9.97E-08
195	8.31E-09	6.72E-10	5.00E-09	5.50E-08
196	9.70E-09	8.00E-10	5.59E-09	9.36E-08
197	6.91E-09	5.72E-10	4.51E-09	4.81E-08
198	7.90E-09	6.62E-10	4.95E-09	5.43E-08
199	1.27E-08	1.02E-09	6.65E-09	1.07E-07
200	9.43E-09	7.92E-10	5.55E-09	9.31E-08
201	1.10E-08	9.34E-10	6.25E-09	1.02E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
202	1.10E-08	9.35E-10	6.25E-09	1.02E-07
203	1.47E-08	9.07E-10	5.96E-09	9.04E-08
204	1.24E-08	1.01E-09	6.61E-09	1.07E-07
205	6.61E-09	5.60E-10	4.45E-09	4.74E-08
206	1.03E-08	8.45E-10	5.81E-09	9.65E-08
207	9.02E-09	7.79E-10	5.49E-09	9.23E-08
208	9.70E-09	8.43E-10	5.81E-09	9.64E-08
209	4.46E-08	3.03E-09	1.58E-08	1.94E-07
210	6.12E-08	4.34E-09	2.16E-08	2.42E-07
211	7.39E-09	7.19E-10	5.20E-09	8.85E-08
212	7.33E-09	7.17E-10	5.19E-09	8.83E-08
213	1.49E-08	1.29E-09	7.92E-09	1.20E-07
214	6.91E-09	6.99E-10	5.10E-09	8.71E-08
215	2.19E-08	1.92E-09	1.08E-08	1.48E-07
216	1.37E-08	1.23E-09	7.63E-09	1.17E-07
217	2.74E-08	2.19E-09	1.21E-08	1.63E-07
218	6.17E-09	6.62E-10	4.92E-09	8.48E-08
219	6.58E-09	7.16E-10	5.19E-09	8.82E-08
220	2.16E-08	1.96E-09	1.10E-08	1.51E-07
221	5.56E-09	6.27E-10	4.75E-09	8.25E-08
222	5.19E-09	6.03E-10	4.63E-09	8.10E-08
223	7.01E-09	8.06E-10	5.63E-09	9.41E-08
224	5.61E-08	4.73E-09	2.34E-08	2.60E-07
225	6.84E-08	5.77E-09	2.81E-08	3.08E-07
226	2.83E-09	2.42E-10	2.89E-09	2.63E-08
227	4.73E-09	5.71E-10	4.47E-09	7.89E-08
228	3.42E-09	3.78E-10	3.55E-09	3.48E-08
229	2.65E-09	2.14E-10	2.74E-09	2.41E-08
230	2.66E-09	2.21E-10	2.78E-09	2.47E-08
231	2.67E-09	1.82E-10	2.58E-09	2.20E-08
232	8.21E-09	6.03E-10	4.67E-09	5.07E-08
233	8.41E-09	6.55E-10	4.92E-09	5.43E-08
234	2.64E-08	1.95E-09	1.10E-08	1.51E-07
235	1.27E-08	9.40E-10	6.29E-09	1.03E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
236	9.03E-09	7.77E-10	5.49E-09	9.26E-08
237	7.97E-09	7.17E-10	5.20E-09	8.88E-08
238	7.95E-09	7.39E-10	5.30E-09	9.01E-08
239	2.95E-08	2.05E-09	1.15E-08	1.57E-07
240	1.64E-08	1.34E-09	8.18E-09	1.24E-07
241	2.74E-09	2.10E-10	2.73E-09	2.41E-08
242	2.17E-08	1.90E-09	1.07E-08	1.48E-07
243	2.58E-08	2.27E-09	1.25E-08	1.69E-07
244	6.42E-08	4.49E-09	2.23E-08	2.51E-07
245	6.70E-09	7.00E-10	5.11E-09	8.77E-08
246	6.10E-09	6.54E-10	4.89E-09	8.47E-08
247	1.91E-08	1.70E-09	9.83E-09	1.40E-07
248	3.38E-09	3.53E-10	3.43E-09	3.32E-08
249	1.55E-08	1.95E-09	1.10E-08	1.51E-07
250	2.38E-08	2.73E-09	1.44E-08	1.82E-07
251	2.31E-08	7.91E-10	5.47E-09	8.75E-08
252	2.79E-08	1.89E-09	1.07E-08	1.49E-07
253	2.84E-08	2.20E-09	1.22E-08	1.66E-07
254	2.78E-08	2.19E-09	1.21E-08	1.66E-07
255	1.81E-08	1.50E-09	8.89E-09	1.30E-07
256	6.82E-08	4.97E-09	2.46E-08	2.76E-07
257	1.51E-08	3.59E-09	1.82E-08	2.10E-07
258	3.10E-08	9.06E-10	5.96E-09	9.03E-08
259	1.53E-08	6.25E-10	4.69E-09	7.88E-08
260	3.23E-08	9.38E-10	6.10E-09	9.19E-08
261	2.85E-08	9.06E-10	5.96E-09	9.04E-08
262	3.13E-08	9.86E-10	6.33E-09	9.44E-08
263	2.80E-08	9.05E-10	5.95E-09	9.04E-08
264	3.38E-08	1.07E-09	6.74E-09	9.88E-08
265	2.79E-08	9.06E-10	5.96E-09	9.04E-08
266	2.91E-08	1.03E-09	6.53E-09	9.67E-08
267	1.83E-08	8.92E-10	5.90E-09	9.03E-08
268	3.63E-08	2.18E-09	1.21E-08	1.66E-07
269	3.37E-08	2.15E-09	1.20E-08	1.64E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
270	1.95E-08	1.05E-09	6.62E-09	9.81E-08
271	5.34E-08	2.93E-09	1.54E-08	1.94E-07
272	2.08E-08	1.46E-09	8.73E-09	1.28E-07
273	4.56E-08	2.77E-09	1.47E-08	1.86E-07
274	2.93E-09	2.19E-10	2.77E-09	2.50E-08
275	1.98E-08	1.38E-09	8.35E-09	1.25E-07
276	4.99E-08	2.91E-09	1.53E-08	1.93E-07
277	9.59E-09	7.95E-10	5.59E-09	9.48E-08
278	4.87E-08	2.90E-09	1.53E-08	1.92E-07
279	5.16E-08	3.34E-09	1.73E-08	2.15E-07
280	3.08E-09	2.39E-10	2.88E-09	2.68E-08
281	1.53E-08	1.14E-09	7.23E-09	1.13E-07
282	4.75E-08	2.88E-09	1.52E-08	1.92E-07
283	2.88E-09	2.16E-10	2.76E-09	2.47E-08
284	2.49E-08	1.86E-09	1.06E-08	1.48E-07
285	4.65E-08	2.87E-09	1.52E-08	1.91E-07
286	5.12E-08	3.17E-09	1.66E-08	2.07E-07
287	4.48E-08	3.00E-09	1.58E-08	1.98E-07
288	4.93E-08	3.31E-09	1.72E-08	2.13E-07
289	5.12E-08	3.44E-09	1.78E-08	2.20E-07
290	1.45E-08	1.12E-09	7.14E-09	1.12E-07
291	4.51E-08	2.87E-09	1.51E-08	1.91E-07
292	7.42E-08	4.19E-09	2.10E-08	2.41E-07
293	6.54E-08	4.03E-09	2.03E-08	2.33E-07
294	8.63E-09	7.10E-10	5.17E-09	8.92E-08
295	4.38E-08	2.85E-09	1.51E-08	1.90E-07
296	3.83E-08	2.70E-09	1.43E-08	1.82E-07
297	8.32E-09	7.01E-10	5.13E-09	8.86E-08
298	7.39E-09	6.50E-10	4.88E-09	8.52E-08
299	4.31E-08	2.84E-09	1.50E-08	1.90E-07
300	4.88E-08	3.39E-09	1.76E-08	2.18E-07
301	1.43E-08	1.26E-09	7.81E-09	1.20E-07
302	2.56E-08	2.07E-09	1.16E-08	1.60E-07
303	1.86E-08	1.61E-09	9.36E-09	1.34E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
304	2.23E-08	1.94E-09	1.09E-08	1.52E-07
305	3.74E-08	2.77E-09	1.47E-08	1.86E-07
306	4.54E-08	3.37E-09	1.75E-08	2.17E-07
307	7.63E-08	5.05E-09	2.49E-08	2.81E-07
308	6.20E-08	4.13E-09	2.07E-08	2.38E-07
309	2.75E-09	2.07E-10	2.71E-09	2.39E-08
310	7.05E-09	6.53E-10	4.89E-09	8.54E-08
311	1.60E-08	1.33E-09	8.09E-09	1.22E-07
312	1.42E-08	1.25E-09	7.71E-09	1.17E-07
313	1.83E-08	1.50E-09	8.89E-09	1.30E-07
314	1.63E-08	1.41E-09	8.47E-09	1.25E-07
315	1.77E-08	1.58E-09	9.26E-09	1.32E-07
316	3.65E-08	2.76E-09	1.46E-08	1.86E-07
317	1.07E-07	6.74E-09	3.20E-08	3.25E-07
318	3.06E-08	2.58E-09	1.38E-08	1.76E-07
319	2.94E-08	2.63E-09	1.40E-08	1.79E-07
320	2.92E-08	2.63E-09	1.40E-08	1.79E-07
321	3.22E-08	1.81E-09	9.91E-09	1.22E-07
322	2.50E-08	2.46E-09	1.32E-08	1.70E-07
323	2.75E-08	2.60E-09	1.39E-08	1.77E-07
324	2.66E-09	1.99E-10	2.67E-09	2.32E-08
325	2.72E-08	2.59E-09	1.38E-08	1.77E-07
326	6.35E-08	4.40E-09	2.20E-08	2.52E-07
327	1.00E-07	6.70E-09	3.18E-08	3.20E-07
328	2.50E-08	2.53E-09	1.35E-08	1.74E-07
329	2.63E-09	1.95E-10	2.65E-09	2.29E-08
330	2.39E-08	2.50E-09	1.34E-08	1.72E-07
331	2.89E-08	3.04E-09	1.59E-08	2.00E-07
332	5.64E-08	4.33E-09	2.17E-08	2.48E-07
333	6.22E-08	4.79E-09	2.38E-08	2.70E-07
334	5.03E-08	4.76E-09	2.36E-08	2.67E-07
335	4.04E-08	4.10E-09	2.06E-08	2.37E-07
336	1.01E-07	6.59E-09	3.14E-08	3.21E-07
337	5.21E-09	5.85E-10	4.56E-09	8.08E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
338	8.21E-09	9.81E-10	6.42E-09	1.01E-07
339	2.38E-08	2.50E-09	1.34E-08	1.72E-07
340	5.51E-08	4.90E-09	2.43E-08	2.74E-07
341	4.18E-08	2.47E-09	1.27E-08	1.42E-07
342	1.92E-08	2.36E-09	1.27E-08	1.65E-07
343	5.50E-08	5.11E-09	2.53E-08	2.85E-07
344	4.84E-08	4.60E-09	2.29E-08	2.61E-07
345	3.73E-09	4.38E-10	3.83E-09	7.10E-08
346	5.60E-09	7.49E-10	5.32E-09	8.85E-08
347	7.75E-09	1.06E-09	6.80E-09	1.06E-07
348	6.62E-09	9.11E-10	6.08E-09	9.69E-08
349	1.23E-08	1.53E-09	8.98E-09	1.29E-07
350	9.56E-09	1.42E-09	8.49E-09	1.23E-07
351	8.24E-09	1.19E-09	7.37E-09	1.10E-07
352	2.74E-08	3.17E-09	1.66E-08	2.07E-07
353	2.27E-08	2.61E-09	1.39E-08	1.78E-07
354	1.85E-08	2.38E-09	1.28E-08	1.66E-07
355	1.82E-08	2.48E-09	1.33E-08	1.71E-07
356	4.83E-08	4.99E-09	2.47E-08	2.79E-07
357	3.98E-08	4.10E-09	2.06E-08	2.37E-07
358	3.98E-08	4.09E-09	2.06E-08	2.37E-07
359	4.38E-08	4.52E-09	2.25E-08	2.57E-07
360	4.83E-08	4.99E-09	2.47E-08	2.79E-07
361	2.93E-08	3.64E-09	1.85E-08	2.15E-07
362	2.61E-08	3.45E-09	1.76E-08	2.06E-07
363	9.93E-08	7.99E-09	3.73E-08	3.59E-07
364	9.57E-09	1.42E-09	8.49E-09	1.23E-07
365	4.83E-08	4.99E-09	2.47E-08	2.79E-07
366	9.16E-09	1.44E-09	8.56E-09	1.24E-07
367	1.40E-08	2.13E-09	1.17E-08	1.53E-07
368	1.53E-08	2.34E-09	1.26E-08	1.64E-07
369	1.26E-08	1.99E-09	1.10E-08	1.45E-07
370	1.37E-08	2.18E-09	1.19E-08	1.55E-07
371	3.35E-09	4.08E-10	3.69E-09	6.89E-08

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
372	2.09E-08	3.35E-09	1.71E-08	2.01E-07
373	6.13E-09	9.24E-10	6.15E-09	9.78E-08
374	2.27E-08	3.49E-09	1.78E-08	2.08E-07
375	2.71E-08	4.06E-09	2.04E-08	2.35E-07
376	3.43E-08	5.20E-09	2.56E-08	2.88E-07
377	2.62E-08	4.02E-09	2.02E-08	2.33E-07
378	1.54E-08	3.05E-09	1.57E-08	1.87E-07
379	9.97E-09	2.63E-09	1.38E-08	1.66E-07
380	1.11E-08	2.88E-09	1.50E-08	1.79E-07
381	9.82E-09	2.99E-09	1.54E-08	1.82E-07
382	4.04E-08	1.14E-09	7.02E-09	9.03E-08
383	3.73E-08	1.15E-09	7.05E-09	9.07E-08
384	3.97E-08	1.33E-09	7.90E-09	9.94E-08
385	3.68E-08	1.15E-09	7.05E-09	9.08E-08
386	4.05E-08	1.25E-09	7.54E-09	9.57E-08
387	3.73E-09	2.36E-10	2.91E-09	1.89E-08
388	7.64E-08	4.27E-09	2.15E-08	2.39E-07
389	2.91E-09	2.05E-10	2.75E-09	1.61E-08
390	2.95E-09	2.11E-10	2.77E-09	1.65E-08
391	6.85E-08	3.98E-09	2.02E-08	2.26E-07
392	6.03E-08	3.82E-09	1.94E-08	2.18E-07
393	2.66E-08	1.97E-09	1.12E-08	1.48E-07
394	4.75E-08	3.21E-09	1.69E-08	2.03E-07
395	6.54E-08	3.96E-09	2.01E-08	2.25E-07
396	7.23E-08	4.38E-09	2.20E-08	2.44E-07
397	2.10E-08	1.61E-09	9.46E-09	1.28E-07
398	6.37E-08	3.95E-09	2.00E-08	2.24E-07
399	6.21E-08	3.94E-09	2.00E-08	2.24E-07
400	6.50E-08	4.72E-09	2.36E-08	2.61E-07
401	1.87E-08	1.59E-09	9.36E-09	1.26E-07
402	4.76E-08	4.02E-09	2.04E-08	2.28E-07
403	1.75E-08	2.10E-09	1.16E-08	1.45E-07
404	1.91E-08	2.31E-09	1.26E-08	1.55E-07
405	5.22E-08	4.44E-09	2.23E-08	2.48E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
406	3.33E-08	3.74E-09	1.91E-08	2.15E-07
407	3.66E-08	4.14E-09	2.09E-08	2.33E-07
408	2.97E-08	4.04E-09	2.04E-08	2.28E-07
409	2.46E-08	3.31E-09	1.70E-08	1.93E-07
410	8.51E-09	1.32E-09	8.04E-09	1.09E-07
411	2.23E-08	2.81E-09	1.50E-08	1.82E-07
412	4.02E-08	4.57E-09	2.29E-08	2.54E-07
413	5.40E-08	6.17E-09	3.02E-08	3.29E-07
414	2.73E-08	3.46E-09	1.78E-08	2.01E-07
415	2.46E-08	3.31E-09	1.70E-08	1.93E-07
416	2.45E-08	3.32E-09	1.71E-08	1.94E-07
417	2.70E-08	3.66E-09	1.86E-08	2.10E-07
418	2.96E-08	4.04E-09	2.04E-08	2.27E-07
419	2.64E-08	3.81E-09	1.93E-08	2.16E-07
420	2.11E-08	3.18E-09	1.64E-08	1.87E-07
421	1.26E-08	2.06E-09	1.14E-08	1.42E-07
422	1.71E-08	3.00E-09	1.56E-08	1.78E-07
423	4.01E-08	5.81E-09	2.80E-08	2.83E-07
424	3.74E-08	1.12E-09	6.92E-09	2.40E-07
425	3.47E-08	1.13E-09	6.95E-09	2.41E-07
426	3.12E-08	1.10E-09	6.84E-09	2.40E-07
427	4.56E-08	1.51E-09	8.56E-09	2.52E-07
428	1.14E-08	5.23E-10	4.23E-09	2.16E-07
429	3.41E-08	1.13E-09	6.95E-09	2.41E-07
430	3.72E-08	1.32E-09	7.83E-09	2.50E-07
431	3.45E-09	2.31E-10	2.84E-09	1.68E-07
432	3.30E-08	1.13E-09	6.96E-09	2.41E-07
433	8.44E-08	3.89E-09	1.98E-08	3.75E-07
434	8.43E-08	3.89E-09	1.98E-08	3.75E-07
435	8.15E-08	3.89E-09	1.97E-08	3.75E-07
436	7.42E-08	4.40E-09	2.21E-08	3.99E-07
437	7.86E-08	4.55E-09	2.28E-08	4.07E-07
438	6.93E-08	4.36E-09	2.19E-08	3.97E-07
439	6.80E-08	3.83E-09	1.95E-08	3.72E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
440	6.68E-08	3.83E-09	1.95E-08	3.72E-07
441	6.22E-08	3.80E-09	1.93E-08	3.71E-07
442	7.58E-08	4.62E-09	2.31E-08	4.10E-07
443	6.00E-08	4.27E-09	2.15E-08	3.93E-07
444	6.06E-08	3.78E-09	1.93E-08	3.70E-07
445	4.22E-08	2.99E-09	1.58E-08	3.45E-07
446	5.95E-08	3.78E-09	1.92E-08	3.70E-07
447	3.00E-08	2.34E-09	1.27E-08	3.10E-07
448	5.79E-08	3.76E-09	1.92E-08	3.69E-07
449	5.19E-08	3.63E-09	1.86E-08	3.62E-07
450	6.13E-08	4.41E-09	2.22E-08	4.00E-07
451	3.99E-08	2.64E-09	1.42E-08	3.26E-07
452	5.53E-08	3.74E-09	1.91E-08	3.68E-07
453	6.01E-08	4.39E-09	2.21E-08	3.99E-07
454	1.30E-08	1.17E-09	7.33E-09	2.55E-07
455	4.65E-08	3.57E-09	1.83E-08	3.59E-07
456	6.64E-08	4.16E-09	2.10E-08	3.86E-07
457	3.42E-08	2.85E-09	1.52E-08	3.37E-07
458	5.99E-08	4.47E-09	2.25E-08	4.03E-07
459	4.77E-08	3.65E-09	1.87E-08	3.64E-07
460	1.16E-08	1.12E-09	7.10E-09	2.52E-07
461	2.12E-08	2.08E-09	1.15E-08	2.96E-07
462	4.69E-08	3.64E-09	1.86E-08	3.63E-07
463	4.20E-08	3.51E-09	1.80E-08	3.56E-07
464	7.61E-08	5.85E-09	2.82E-08	4.35E-07
465	9.19E-09	1.02E-09	6.63E-09	2.46E-07
466	3.77E-08	3.50E-09	1.80E-08	3.56E-07
467	5.16E-08	4.47E-09	2.24E-08	4.03E-07
468	3.51E-08	3.45E-09	1.77E-08	3.53E-07
469	3.47E-08	3.44E-09	1.77E-08	3.53E-07
470	3.23E-08	3.39E-09	1.74E-08	3.50E-07
471	1.80E-07	1.07E-08	4.79E-08	8.37E-07
472	3.09E-08	3.35E-09	1.73E-08	3.49E-07
473	5.02E-08	5.50E-09	2.72E-08	4.52E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
474	6.55E-08	6.02E-09	2.89E-08	4.43E-07
475	1.32E-07	9.00E-09	4.14E-08	8.05E-07
476	9.39E-08	8.62E-09	3.97E-08	7.89E-07
477	1.15E-07	1.06E-08	4.82E-08	8.62E-07
478	1.08E-08	1.37E-09	8.30E-09	2.65E-07
479	1.87E-08	2.24E-09	1.23E-08	3.04E-07
480	1.37E-08	1.81E-09	1.03E-08	2.81E-07
481	3.08E-08	3.35E-09	1.72E-08	3.48E-07
482	3.69E-08	4.04E-09	2.04E-08	3.82E-07
483	3.04E-08	3.53E-09	1.81E-08	3.57E-07
484	5.29E-08	5.65E-09	2.72E-08	4.26E-07
485	1.17E-07	8.60E-09	4.01E-08	5.30E-07
486	2.70E-08	3.24E-09	1.68E-08	3.43E-07
487	1.16E-07	9.07E-09	4.18E-08	8.08E-07
488	2.49E-08	3.18E-09	1.64E-08	3.40E-07
489	2.33E-08	3.12E-09	1.62E-08	3.37E-07
490	3.15E-08	4.03E-09	2.04E-08	3.82E-07
491	2.61E-08	3.32E-09	1.71E-08	3.47E-07
492	2.86E-08	3.65E-09	1.86E-08	3.63E-07
493	3.15E-08	4.03E-09	2.04E-08	3.81E-07
494	2.15E-08	3.06E-09	1.59E-08	3.34E-07
495	1.94E-08	2.91E-09	1.52E-08	3.26E-07
496	2.13E-08	3.22E-09	1.66E-08	3.41E-07
497	6.26E-08	6.74E-09	3.22E-08	4.74E-07
498	4.74E-08	5.80E-09	2.79E-08	4.33E-07
499	1.00E-07	9.12E-09	4.20E-08	8.10E-07
500	1.11E-07	1.01E-08	4.63E-08	8.47E-07
501	2.33E-08	3.54E-09	1.81E-08	3.57E-07
502	2.09E-08	3.34E-09	1.72E-08	3.47E-07
503	1.23E-07	1.12E-08	5.10E-08	8.87E-07
504	1.84E-08	2.92E-09	1.53E-08	3.27E-07
505	1.67E-08	2.79E-09	1.46E-08	3.20E-07
506	8.86E-08	9.14E-09	4.21E-08	8.10E-07
507	1.79E-08	3.05E-09	1.59E-08	3.33E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
508	4.46E-08	6.81E-09	3.22E-08	4.62E-07
509	7.47E-08	9.13E-09	4.20E-08	8.10E-07
510	1.46E-08	2.92E-09	1.52E-08	3.26E-07
511	1.31E-08	2.63E-09	1.39E-08	3.12E-07
512	1.54E-08	2.86E-09	1.49E-08	3.24E-07
513	6.19E-08	2.48E-09	1.35E-08	3.22E-07
514	2.79E-08	1.05E-09	6.63E-09	2.39E-07
515	4.61E-08	1.48E-09	8.48E-09	2.53E-07
516	7.96E-08	2.32E-09	1.19E-08	5.47E-07
517	6.08E-08	2.47E-09	1.34E-08	3.21E-07
518	7.41E-08	3.00E-09	1.59E-08	3.50E-07
519	9.64E-08	4.14E-09	2.10E-08	3.92E-07
520	4.55E-08	1.48E-09	8.50E-09	2.53E-07
521	4.84E-08	1.55E-09	8.76E-09	2.54E-07
522	5.40E-08	2.38E-09	1.30E-08	3.16E-07
523	4.55E-08	1.49E-09	8.50E-09	2.53E-07
524	4.15E-08	1.47E-09	8.44E-09	2.52E-07
525	6.78E-08	2.01E-09	1.07E-08	5.42E-07
526	1.19E-07	5.45E-09	2.66E-08	4.28E-07
527	1.15E-07	5.46E-09	2.66E-08	4.29E-07
528	4.20E-08	2.72E-09	1.46E-08	3.35E-07
529	1.22E-07	6.55E-09	3.16E-08	4.77E-07
530	3.20E-08	2.21E-09	1.22E-08	3.07E-07
531	4.87E-08	3.50E-09	1.80E-08	3.61E-07
532	1.11E-07	5.76E-09	2.79E-08	4.38E-07
533	1.64E-07	7.13E-09	3.37E-08	4.79E-07
534	9.58E-08	5.45E-09	2.66E-08	4.29E-07
535	3.54E-08	2.97E-09	1.58E-08	3.48E-07
536	2.59E-08	2.09E-09	1.17E-08	3.00E-07
537	2.84E-08	2.30E-09	1.26E-08	3.12E-07
538	3.12E-08	2.53E-09	1.37E-08	3.25E-07
539	4.00E-08	3.37E-09	1.74E-08	3.54E-07
540	9.54E-08	6.01E-09	2.91E-08	4.54E-07
541	8.52E-08	6.28E-09	3.03E-08	4.65E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
542	1.59E-07	9.89E-09	4.55E-08	8.46E-07
543	2.50E-08	2.08E-09	1.16E-08	2.99E-07
544	8.41E-08	5.43E-09	2.65E-08	4.28E-07
545	9.23E-08	6.00E-09	2.91E-08	4.53E-07
546	4.69E-08	3.86E-09	1.97E-08	3.79E-07
547	8.07E-08	5.41E-09	2.64E-08	4.27E-07
548	4.08E-08	3.75E-09	1.92E-08	3.73E-07
549	3.52E-08	3.36E-09	1.74E-08	3.54E-07
550	2.84E-08	2.89E-09	1.52E-08	3.30E-07
551	6.94E-08	5.35E-09	2.61E-08	4.25E-07
552	1.26E-07	9.08E-09	4.17E-08	8.03E-07
553	1.57E-08	1.80E-09	1.03E-08	2.84E-07
554	7.97E-08	7.82E-09	3.69E-08	5.11E-07
555	1.56E-08	1.80E-09	1.03E-08	2.84E-07
556	5.68E-08	5.24E-09	2.56E-08	4.19E-07
557	4.74E-08	5.11E-09	2.50E-08	4.13E-07
558	4.29E-08	4.95E-09	2.43E-08	4.06E-07
559	1.10E-07	8.64E-09	4.01E-08	8.00E-07
560	1.28E-07	9.57E-09	4.39E-08	8.23E-07
561	1.41E-07	1.06E-08	4.83E-08	8.61E-07
562	1.49E-07	1.06E-08	4.77E-08	8.43E-07
563	2.01E-07	1.43E-08	6.40E-08	9.78E-07
564	4.71E-08	5.10E-09	2.50E-08	4.13E-07
565	9.47E-08	8.10E-09	3.81E-08	5.19E-07
566	1.61E-08	2.57E-09	1.37E-08	3.13E-07
567	4.04E-08	5.12E-09	2.50E-08	4.14E-07
568	4.45E-08	5.65E-09	2.75E-08	4.37E-07
569	4.90E-08	6.25E-09	3.02E-08	4.64E-07
570	1.00E-07	1.06E-08	4.88E-08	8.76E-07
571	1.65E-08	2.67E-09	1.41E-08	3.18E-07
572	5.53E-09	1.69E-09	9.56E-09	2.67E-07
573	8.53E-08	3.22E-09	1.69E-08	6.57E-07
574	6.67E-08	1.91E-09	1.03E-08	8.42E-07
575	1.13E-07	4.01E-09	2.04E-08	6.86E-07

Pipeline	Methane Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
576	6.59E-08	1.92E-09	1.03E-08	8.42E-07
577	1.83E-07	7.51E-09	3.54E-08	1.07E-06
578	7.71E-08	4.71E-09	2.37E-08	7.21E-07
579	1.50E-08	1.56E-09	9.18E-09	5.75E-07
580	1.83E-08	3.38E-09	1.74E-08	6.51E-07
581	1.53E-08	2.78E-09	1.46E-08	6.22E-07
582	1.67E-08	3.07E-09	1.60E-08	6.36E-07
583	1.3E-08	2.81E-09	1.48E-08	6.23E-07
584	9.00E-08	7.57E-09	3.67E-08	8.47E-07

13.3 Comparison

In the following table, the differences have been calculated as new failure rates – old failure rates i.e. the failure rates using version 3.1 of PIPIN – the failure rates using version 3.04 of PIPIN. The percentages are then the difference divided by

Table 17 Comparison of the methane failure rates using versions 3.04 and 3.1 of PIPIN

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
1	-2.0E-11	0.0E+00	0.0E+00	0.0E+00	-0.8	0.0	0.0	0.0
2	-1.0E-10	-1.0E-12	0.0E+00	-1.0E-10	-3.6	-0.6	0.0	-0.5
3	-1.6E-10	-1.0E-12	-1.0E-11	-1.0E-10	-5.4	-0.5	-0.4	-0.5
4	-2.5E-10	-1.0E-12	-1.0E-11	-1.0E-10	-7.6	-0.5	-0.4	-0.4
5	-1.5E-10	-2.0E-12	-1.0E-11	-2.0E-10	-5.1	-1.1	-0.4	-0.9
6	-1.4E-10	-1.0E-12	-1.0E-11	-2.0E-10	-4.9	-0.6	-0.4	-0.9
7	-3.9E-10	-3.0E-12	-1.0E-11	-3.0E-10	-10.3	-1.5	-0.4	-1.3
8	-4.6E-10	-1.2E-11	-5.0E-11	-9.0E-10	-12.0	-5.4	-1.8	-3.6
9	-8.0E-11	-5.0E-12	-3.0E-11	-5.0E-10	-3.0	-2.8	-1.2	-2.3
10	-3.7E-10	-2.0E-12	-1.0E-11	-2.0E-10	-8.7	-0.9	-0.4	-0.8
11	-3.1E-10	-3.0E-12	-1.0E-11	-3.0E-10	-8.2	-1.5	-0.4	-1.3
12	-2.7E-10	-4.0E-12	-2.0E-11	-4.0E-10	-7.7	-2.0	-0.7	-1.7
13	-2.1E-10	-3.0E-12	-1.0E-11	-3.0E-10	-6.4	-1.5	-0.4	-1.3
14	-2.0E-11	-1.0E-12	-1.0E-11	-2.0E-10	-0.8	-0.6	-0.4	-0.9

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
15	-3.1E-10	-2.1E-11	-1.1E-10	-1.8E-09	-9.8	-9.3	-3.9	-7.1
16	-6.8E-10	-5.0E-11	-2.5E-10	-3.9E-09	-17.2	-16.1	-7.7	-12.4
17	-7.8E-10	-5.0E-12	-2.0E-11	-4.0E-10	-12.5	-2.0	-0.7	-1.5
18	-1.1E-10	-2.0E-12	-1.0E-11	-3.0E-10	-3.9	-1.1	-0.4	-1.4
19	-5.9E-10	-8.0E-12	-4.0E-11	-6.0E-10	-12.3	-3.5	-1.4	-2.4
20	-6.5E-10	-8.0E-12	-4.0E-11	-7.0E-10	-12.9	-3.4	-1.4	-2.7
21	-7.3E-10	-1.0E-11	-5.0E-11	-8.0E-10	-13.7	-4.1	-1.7	-3.0
22	-4.9E-10	-7.0E-12	-3.0E-11	-6.0E-10	-11.3	-3.2	-1.1	-2.4
23	-1.3E-10	-3.0E-12	-1.0E-11	-3.0E-10	-4.6	-1.6	-0.4	-1.4
24	-8.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-2.9	-1.1	-0.4	-0.9
25	-9.0E-11	-2.0E-12	-1.0E-11	-3.0E-10	-3.3	-1.1	-0.4	-1.4
26	-1.0E-10	-2.0E-12	-1.0E-11	-3.0E-10	-3.6	-1.1	-0.4	-1.4
27	-2.1E-10	-4.0E-12	-2.0E-11	-4.0E-10	-6.7	-2.1	-0.8	-1.8
28	-5.3E-10	-9.0E-12	-5.0E-11	-7.0E-10	-12.2	-4.0	-1.8	-2.8
29	-5.3E-10	-9.0E-12	-5.0E-11	-7.0E-10	-12.2	-4.0	-1.8	-2.8
30	-6.5E-10	-1.1E-11	-6.0E-11	-8.0E-10	-13.6	-4.6	-2.1	-3.1
31	-6.5E-10	-1.1E-11	-6.0E-11	-8.0E-10	-13.6	-4.6	-2.1	-3.1
32	-6.5E-10	-1.1E-11	-6.0E-11	-8.0E-10	-13.6	-4.6	-2.1	-3.1
33	-6.6E-10	-1.1E-11	-6.0E-11	-8.0E-10	-13.8	-4.6	-2.1	-3.1
34	-5.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-1.9	-1.1	-0.4	-0.9
35	-3.0E-10	-1.2E-11	-6.0E-11	-1.0E-09	-9.3	-5.7	-2.2	-4.2
36	-2.4E-10	-1.2E-11	-6.0E-11	-9.0E-10	-7.9	-5.8	-2.2	-3.8
37	-2.7E-10	-1.4E-11	-7.0E-11	-1.1E-09	-8.7	-6.6	-2.6	-4.6
38	-7.0E-10	-4.4E-11	-2.3E-10	-3.5E-09	-17.4	-14.7	-7.2	-11.4
39	-2.0E-09	-8.7E-11	-4.2E-10	-5.0E-09	-23.3	-15.4	-9.5	-6.6
40	-5.0E-10	-4.1E-11	-2.1E-10	-3.2E-09	-14.1	-14.5	-6.8	-10.8
41	-1.4E-10	-3.0E-12	-1.0E-11	-2.0E-10	-3.5	-1.4	-0.4	-0.8
42	-1.5E-10	-3.0E-12	-2.0E-11	-2.0E-10	-3.6	-1.4	-0.7	-0.8
43	-3.4E-10	-5.0E-12	-2.0E-11	-4.0E-10	-5.4	-1.9	-0.7	-1.4
44	-2.0E-10	-3.0E-12	-2.0E-11	-2.0E-10	-4.4	-1.3	-0.7	-0.8
45	-3.0E-11	-1.0E-12	-1.0E-11	0.0E+00	-1.1	-0.6	-0.4	0.0
46	-1.3E-10	-3.0E-12	-1.0E-11	-3.0E-10	-3.5	-1.4	-0.4	-1.2
47	-1.6E-10	-4.0E-12	-2.0E-11	-3.0E-10	-4.0	-1.8	-0.7	-1.2

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
48	-1.6E-10	-4.0E-12	-2.0E-11	-3.0E-10	-4.0	-1.8	-0.7	-1.2
49	-2.8E-10	-5.0E-12	-2.0E-11	-4.0E-10	-5.0	-1.9	-0.7	-1.5
50	-3.2E-10	-6.0E-12	-3.0E-11	-5.0E-10	-5.3	-2.2	-1.0	-1.8
51	-3.5E-10	-7.0E-12	-3.0E-11	-4.0E-10	-5.5	-2.5	-1.0	-1.4
52	-2.1E-10	-4.0E-12	-2.0E-11	-3.0E-10	-4.5	-1.7	-0.7	-1.2
53	-5.0E-11	-3.0E-12	-1.0E-11	-3.0E-10	-1.8	-1.6	-0.4	-1.3
54	-4.0E-11	-3.0E-12	-1.0E-11	-2.0E-10	-1.4	-1.6	-0.4	-0.9
55	-7.0E-11	-3.0E-12	-1.0E-11	-3.0E-10	-2.3	-1.4	-0.4	-1.3
56	-1.2E-10	-5.0E-12	-2.0E-11	-4.0E-10	-3.4	-2.2	-0.7	-1.6
57	-4.0E-11	-2.0E-12	-2.0E-11	-3.0E-10	-1.5	-1.1	-0.8	-1.3
58	-3.0E-11	-3.0E-12	-1.0E-11	-3.0E-10	-1.1	-1.6	-0.4	-1.3
59	-4.0E-11	-3.0E-12	-1.0E-11	-3.0E-10	-1.4	-1.5	-0.4	-1.3
60	-2.1E-10	-1.2E-11	-6.0E-11	-9.0E-10	-5.1	-4.1	-1.9	-3.0
61	-2.4E-10	-1.3E-11	-7.0E-11	-1.0E-09	-5.6	-4.2	-2.2	-3.2
62	-2.4E-10	-1.3E-11	-6.0E-11	-1.0E-09	-5.6	-4.2	-1.9	-3.2
63	-1.1E-10	-5.0E-12	-3.0E-11	-4.0E-10	-3.2	-2.2	-1.1	-1.6
64	-1.2E-10	-6.0E-12	-3.0E-11	-4.0E-10	-3.4	-2.5	-1.0	-1.6
65	-9.0E-11	-5.0E-12	-2.0E-11	-4.0E-10	-2.9	-2.2	-0.7	-1.6
66	-2.0E-11	-1.0E-12	0.0E+00	-2.0E-10	-0.8	-0.5	0.0	-0.9
67	-2.1E-10	-1.3E-11	-7.0E-11	-1.1E-09	-5.4	-4.5	-2.2	-3.6
68	-2.4E-10	-1.5E-11	-8.0E-11	-1.2E-09	-5.7	-4.7	-2.4	-3.7
69	-1.7E-10	-1.2E-11	-6.0E-11	-9.0E-10	-4.5	-4.2	-1.9	-3.0
70	-1.5E-10	-1.0E-11	-5.0E-11	-8.0E-10	-4.1	-3.6	-1.6	-2.7
71	-3.3E-10	-1.9E-11	-9.0E-11	-1.5E-09	-6.5	-4.9	-2.5	-4.1
72	-5.6E-10	-4.5E-11	-2.3E-10	-3.2E-09	-8.3	-6.9	-4.7	-6.0
73	-6.3E-10	-5.1E-11	-2.5E-10	-3.1E-09	-7.8	-5.8	-4.2	-3.2
74	-4.0E-11	-7.0E-12	-4.0E-11	-6.0E-10	-1.4	-2.8	-1.4	-2.2
75	-2.9E-10	-7.0E-12	-3.0E-11	-4.0E-10	-5.4	-2.7	-1.0	-1.5
76	-9.0E-10	-1.2E-11	-6.0E-11	-8.0E-10	-6.2	-2.6	-1.5	-1.1
77	-6.0E-11	-1.0E-12	-1.0E-11	-2.0E-10	-2.0	-0.5	-0.4	-0.9
78	-2.6E-10	-7.0E-12	-4.0E-11	-5.0E-10	-5.2	-2.7	-1.4	-1.8
79	-2.1E-10	-5.0E-12	-3.0E-11	-4.0E-10	-4.6	-2.1	-1.0	-1.5
80	-2.4E-10	-6.0E-12	-3.0E-11	-4.0E-10	-5.0	-2.4	-1.0	-1.5

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
81	-2.5E-10	-7.0E-12	-4.0E-11	-4.0E-10	-5.0	-2.7	-1.4	-1.5
82	-8.0E-10	-1.3E-11	-6.0E-11	-7.0E-10	-6.3	-2.9	-1.6	-1.0
83	-1.0E-09	-1.6E-11	-8.0E-11	-1.0E-09	-6.6	-3.2	-1.9	-1.4
84	-7.0E-10	-1.3E-11	-7.0E-11	-8.0E-10	-5.6	-2.9	-1.8	-1.1
85	-8.0E-10	-1.2E-11	-6.0E-11	-8.0E-10	-6.4	-2.7	-1.6	-1.1
86	-5.1E-10	-1.4E-11	-7.0E-11	-9.0E-10	-6.2	-3.4	-1.9	-1.3
87	-1.1E-10	-6.0E-12	-3.0E-11	-5.0E-10	-3.4	-2.7	-1.1	-2.0
88	-1.3E-10	-6.0E-12	-3.0E-11	-6.0E-10	-3.9	-2.6	-1.1	-2.3
89	-8.0E-11	-4.0E-12	-1.0E-11	-3.0E-10	-2.5	-1.9	-0.4	-1.3
90	-4.8E-10	-1.4E-11	-7.0E-11	-9.0E-10	-6.1	-3.4	-1.9	-1.3
91	-3.7E-10	-1.7E-11	-8.0E-11	-1.2E-09	-6.8	-4.7	-2.3	-3.4
92	-2.3E-10	-1.2E-11	-6.0E-11	-9.0E-10	-5.4	-4.0	-1.9	-2.9
93	-1.2E-10	-5.0E-12	-3.0E-11	-4.0E-10	-3.4	-2.2	-1.1	-1.6
94	-3.6E-10	-1.8E-11	-9.0E-11	-1.4E-09	-6.5	-4.7	-2.5	-3.8
95	-4.3E-10	-2.1E-11	-1.1E-10	-1.6E-09	-7.3	-5.2	-3.0	-4.2
96	-4.3E-10	-2.1E-11	-1.1E-10	-1.6E-09	-7.3	-5.2	-3.0	-4.2
97	-4.0E-10	-1.4E-11	-7.0E-11	-9.0E-10	-5.8	-3.5	-1.9	-1.3
98	-3.5E-10	-1.8E-11	-9.0E-11	-1.4E-09	-6.6	-4.8	-2.5	-3.9
99	-3.9E-10	-1.4E-11	-7.0E-11	-9.0E-10	-6.0	-3.5	-1.9	-1.3
100	-3.7E-10	-1.9E-11	-1.0E-10	-1.5E-09	-6.7	-4.8	-2.7	-4.0
101	-3.4E-10	-1.9E-11	-9.0E-11	-1.4E-09	-6.6	-5.1	-2.6	-3.9
102	-2.0E-11	-2.0E-12	0.0E+00	-2.0E-10	-0.7	-1.1	0.0	-0.9
103	-2.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-0.7	-1.1	-0.4	-0.9
104	-7.0E-11	-5.0E-12	-3.0E-11	-4.0E-10	-2.3	-2.3	-1.1	-1.6
105	-9.0E-11	-6.0E-12	-4.0E-11	-5.0E-10	-2.9	-2.7	-1.4	-1.9
106	-2.1E-10	-1.3E-11	-7.0E-11	-1.1E-09	-5.1	-4.3	-2.2	-3.5
107	-2.3E-10	-1.4E-11	-7.0E-11	-1.1E-09	-5.4	-4.4	-2.1	-3.4
108	-3.0E-10	-1.6E-11	-8.0E-11	-1.3E-09	-6.0	-4.4	-2.3	-3.7
109	-3.7E-10	-2.1E-11	-1.0E-10	-1.6E-09	-7.0	-5.4	-2.8	-4.3
110	-4.1E-10	-2.2E-11	-1.1E-10	-1.7E-09	-7.0	-5.1	-2.9	-4.2
111	-3.8E-10	-1.5E-11	-8.0E-11	-1.0E-09	-5.8	-3.6	-2.1	-1.4
112	-3.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-1.1	-1.1	-0.4	-0.9
113	-2.3E-10	-1.3E-11	-7.0E-11	-1.1E-09	-5.5	-4.3	-2.2	-3.5

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
114	-2.8E-10	-1.6E-11	-8.0E-11	-1.3E-09	-6.1	-4.8	-2.4	-3.8
115	-2.8E-10	-1.7E-11	-9.0E-11	-1.3E-09	-6.1	-5.1	-2.7	-3.8
116	-3.1E-10	-1.8E-11	-9.0E-11	-1.4E-09	-6.5	-5.1	-2.6	-4.0
117	-3.9E-10	-2.3E-11	-1.1E-10	-1.9E-09	-7.3	-5.8	-3.0	-4.9
118	-2.9E-10	-1.6E-11	-8.0E-11	-1.3E-09	-5.9	-4.4	-2.3	-3.7
119	-3.5E-10	-1.4E-11	-7.0E-11	-9.0E-10	-5.8	-3.6	-1.9	-1.3
120	-4.4E-10	-1.8E-11	-9.0E-11	-1.2E-09	-6.4	-4.1	-2.3	-1.7
121	-2.3E-10	-1.4E-11	-7.0E-11	-1.1E-09	-5.5	-4.6	-2.2	-3.5
122	-3.0E-10	-1.7E-11	-9.0E-11	-1.3E-09	-6.1	-4.7	-2.6	-3.7
123	-3.3E-10	-2.0E-11	-1.0E-10	-1.5E-09	-6.4	-5.2	-2.8	-4.1
124	-1.9E-10	-1.3E-11	-6.0E-11	-1.0E-09	-4.9	-4.3	-1.9	-3.2
125	-3.2E-10	-2.0E-11	-1.0E-10	-1.6E-09	-6.3	-5.1	-2.7	-4.3
126	-3.7E-10	-1.6E-11	-8.0E-11	-1.1E-09	-5.9	-3.7	-2.1	-1.6
127	-3.0E-10	-1.4E-11	-7.0E-11	-9.0E-10	-5.4	-3.6	-2.0	-1.3
128	-1.4E-10	-1.0E-11	-5.0E-11	-8.0E-10	-3.9	-3.6	-1.6	-2.7
129	-1.8E-10	-1.3E-11	-7.0E-11	-1.0E-09	-4.7	-4.4	-2.2	-3.2
130	-1.2E-09	-5.5E-11	-2.7E-10	-4.0E-09	-8.6	-5.5	-4.1	-3.8
131	-1.1E-09	-3.3E-11	-1.6E-10	-1.8E-09	-6.1	-3.5	-2.6	-1.9
132	-6.3E-10	-3.6E-11	-1.8E-10	-2.6E-09	-8.3	-6.2	-3.9	-5.2
133	-2.4E-10	-1.6E-11	-7.0E-11	-1.2E-09	-5.5	-4.7	-2.1	-3.5
134	-1.0E-09	-5.3E-11	-2.6E-10	-3.0E-09	-7.6	-5.4	-4.0	-2.9
135	-1.7E-10	-1.4E-11	-8.0E-11	-1.1E-09	-4.5	-4.4	-2.4	-3.4
136	-3.0E-11	-3.0E-12	-1.0E-11	-2.0E-10	-1.1	-1.6	-0.4	-0.9
137	-1.0E-09	-6.1E-11	-3.0E-10	-4.0E-09	-8.7	-6.2	-4.6	-3.8
138	-1.2E-09	-7.0E-11	-3.5E-10	-5.0E-09	-9.0	-6.0	-4.8	-4.3
139	-7.9E-10	-5.3E-11	-2.6E-10	-3.3E-09	-7.9	-5.9	-4.3	-3.3
140	-1.1E-09	-7.0E-11	-3.6E-10	-5.0E-09	-9.3	-6.3	-5.1	-4.5
141	-6.9E-10	-4.8E-11	-2.3E-10	-3.0E-09	-7.8	-5.6	-3.9	-3.1
142	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0	0.0	0.0	0.0
143	0.0E+00	-1.0E-12	-1.0E-11	-1.0E-10	0.0	-0.6	-0.4	-0.5
144	-1.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-0.4	-1.1	-0.4	-0.9
145	-5.2E-10	-4.8E-11	-2.3E-10	-3.0E-09	-7.5	-5.9	-4.1	-3.2
146	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0	0.0	0.0	0.0

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
147	-2.0E-11	-4.0E-12	-2.0E-11	-3.0E-10	-0.8	-1.9	-0.7	-1.3
148	-3.0E-11	-6.0E-12	-3.0E-11	-4.0E-10	-1.1	-2.6	-1.1	-1.6
149	-4.0E-11	-7.0E-12	-4.0E-11	-6.0E-10	-1.4	-2.9	-1.4	-2.3
150	-5.0E-11	-8.0E-12	-4.0E-11	-6.0E-10	-1.8	-3.1	-1.4	-2.2
151	-4.4E-10	-1.0E-11	-5.0E-11	-8.0E-10	-6.6	-3.2	-1.6	-2.6
152	-6.0E-10	-3.3E-11	-1.7E-10	-2.5E-09	-8.3	-6.0	-3.9	-5.2
153	-5.8E-10	-3.3E-11	-1.7E-10	-2.5E-09	-8.1	-6.1	-3.9	-5.2
154	-1.4E-09	-7.0E-11	-3.6E-10	-5.0E-09	-8.6	-6.0	-4.9	-4.3
155	-4.9E-10	-3.3E-11	-1.6E-10	-2.4E-09	-7.8	-6.4	-3.8	-5.3
156	-6.9E-10	-5.9E-11	-2.9E-10	-3.8E-09	-8.6	-6.8	-4.9	-3.9
157	-4.3E-10	-5.0E-11	-2.4E-10	-3.2E-09	-7.2	-6.4	-4.4	-3.5
158	-2.1E-10	-5.0E-12	-2.0E-11	-4.0E-10	-4.8	-2.2	-0.7	-1.6
159	-5.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-1.8	-1.1	-0.4	-0.9
160	-1.6E-10	-4.0E-12	-3.0E-11	-4.0E-10	-4.2	-1.8	-1.1	-1.6
161	-1.7E-10	-5.0E-12	-3.0E-11	-4.0E-10	-4.3	-2.2	-1.1	-1.6
162	-1.9E-10	-7.0E-12	-3.0E-11	-5.0E-10	-4.6	-2.9	-1.0	-1.9
163	-3.9E-10	-1.0E-11	-5.0E-11	-7.0E-10	-6.0	-3.2	-1.5	-2.3
164	-5.7E-10	-1.3E-11	-6.0E-11	-8.0E-10	-6.1	-3.3	-1.7	-1.2
165	-6.7E-10	-1.5E-11	-8.0E-11	-1.0E-09	-6.6	-3.5	-2.1	-1.4
166	-7.0E-10	-1.6E-11	-8.0E-11	-1.0E-09	-6.4	-3.5	-2.1	-1.4
167	-1.7E-10	-5.0E-12	-3.0E-11	-4.0E-10	-4.3	-2.2	-1.1	-1.6
168	-1.9E-10	-6.0E-12	-3.0E-11	-4.0E-10	-4.6	-2.5	-1.0	-1.5
169	-5.7E-10	-1.3E-11	-6.0E-11	-8.0E-10	-6.2	-3.3	-1.7	-1.2
170	-6.3E-10	-1.4E-11	-7.0E-11	-1.0E-09	-6.4	-3.3	-1.9	-1.4
171	-7.0E-10	-1.6E-11	-8.0E-11	-1.1E-09	-6.5	-3.6	-2.1	-1.5
172	-5.8E-10	-1.3E-11	-6.0E-11	-8.0E-10	-6.3	-3.3	-1.7	-1.2
173	-3.8E-10	-1.3E-11	-7.0E-11	-9.0E-10	-5.8	-3.4	-2.0	-1.3
174	-9.7E-10	-4.0E-11	-1.9E-10	-2.8E-09	-8.9	-5.7	-3.7	-4.9
175	-8.9E-10	-4.0E-11	-2.0E-10	-2.8E-09	-8.6	-5.9	-4.0	-5.0
176	-1.0E-09	-4.5E-11	-2.2E-10	-3.1E-09	-8.8	-6.1	-4.1	-5.2
177	-1.2E-09	-5.3E-11	-2.6E-10	-3.5E-09	-8.4	-5.7	-4.2	-3.4
178	-5.9E-10	-2.1E-11	-9.0E-11	-1.3E-09	-5.9	-3.9	-2.1	-1.7
179	-7.1E-10	-3.4E-11	-1.7E-10	-2.4E-09	-8.0	-5.5	-3.6	-4.7

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
180	-2.6E-10	-1.6E-11	-8.0E-11	-1.3E-09	-5.7	-4.5	-2.3	-3.7
181	-1.0E-09	-5.0E-11	-2.4E-10	-2.8E-09	-7.7	-5.5	-3.9	-2.8
182	-1.3E-09	-6.0E-11	-3.0E-10	-4.0E-09	-8.4	-5.6	-4.3	-3.6
183	-2.1E-10	-1.4E-11	-6.0E-11	-1.1E-09	-5.1	-4.4	-1.8	-3.4
184	-2.7E-10	-1.7E-11	-9.0E-11	-1.3E-09	-6.1	-4.9	-2.6	-3.8
185	-8.5E-10	-4.4E-11	-2.2E-10	-3.1E-09	-8.7	-6.3	-4.3	-5.4
186	-6.7E-10	-3.6E-11	-1.8E-10	-2.5E-09	-7.9	-5.6	-3.7	-4.7
187	-1.1E-09	-5.2E-11	-2.6E-10	-4.0E-09	-8.1	-5.4	-4.0	-3.8
188	-1.3E-09	-6.2E-11	-2.9E-10	-4.0E-09	-8.8	-5.8	-4.2	-3.6
189	-8.7E-10	-4.9E-11	-2.4E-10	-3.4E-09	-8.5	-6.5	-4.4	-5.6
190	-7.5E-10	-3.9E-11	-2.0E-10	-2.7E-09	-8.5	-6.1	-4.1	-5.1
191	-1.2E-09	-5.9E-11	-2.9E-10	-4.0E-09	-8.6	-6.1	-4.5	-3.8
192	-2.2E-10	-1.5E-11	-7.0E-11	-1.2E-09	-5.3	-4.6	-2.1	-3.6
193	-1.0E-09	-4.9E-11	-2.5E-10	-3.2E-09	-8.6	-5.6	-4.2	-3.3
194	-1.0E-09	-5.4E-11	-2.6E-10	-3.3E-09	-8.0	-5.7	-4.1	-3.2
195	-7.8E-10	-4.5E-11	-2.2E-10	-3.1E-09	-8.6	-6.3	-4.2	-5.3
196	-9.0E-10	-4.6E-11	-2.3E-10	-3.0E-09	-8.5	-5.4	-4.0	-3.1
197	-5.9E-10	-3.5E-11	-1.7E-10	-2.5E-09	-7.9	-5.8	-3.6	-4.9
198	-7.4E-10	-4.6E-11	-2.3E-10	-3.2E-09	-8.6	-6.5	-4.4	-5.6
199	-1.2E-09	-6.0E-11	-3.3E-10	-5.0E-09	-8.6	-5.6	-4.7	-4.5
200	-8.7E-10	-4.7E-11	-2.3E-10	-3.1E-09	-8.4	-5.6	-4.0	-3.2
201	-1.0E-09	-5.8E-11	-2.8E-10	-4.0E-09	-8.3	-5.8	-4.3	-3.8
202	-1.0E-09	-5.8E-11	-2.9E-10	-4.0E-09	-8.3	-5.8	-4.4	-3.8
203	-1.0E-09	-3.3E-11	-1.5E-10	-1.7E-09	-6.4	-3.5	-2.5	-1.8
204	-1.2E-09	-6.0E-11	-3.2E-10	-4.0E-09	-8.8	-5.6	-4.6	-3.6
205	-5.5E-10	-3.6E-11	-1.8E-10	-2.5E-09	-7.7	-6.0	-3.9	-5.0
206	-9.0E-10	-5.3E-11	-2.6E-10	-3.5E-09	-8.0	-5.9	-4.3	-3.5
207	-7.6E-10	-4.4E-11	-2.2E-10	-2.9E-09	-7.8	-5.3	-3.9	-3.0
208	-9.0E-10	-5.4E-11	-2.6E-10	-3.4E-09	-8.5	-6.0	-4.3	-3.4
209	-3.3E-09	-1.2E-10	-6.0E-10	-7.0E-09	-6.9	-3.8	-3.7	-3.5
210	-4.1E-09	-1.4E-10	-6.0E-10	-6.0E-09	-6.3	-3.1	-2.7	-2.4
211	-6.2E-10	-4.3E-11	-2.1E-10	-2.8E-09	-7.7	-5.6	-3.9	-3.1
212	-6.2E-10	-4.3E-11	-2.1E-10	-2.8E-09	-7.8	-5.7	-3.9	-3.1

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
213	-1.2E-09	-8.0E-11	-3.7E-10	-4.0E-09	-7.5	-5.8	-4.5	-3.2
214	-5.6E-10	-4.1E-11	-2.0E-10	-2.7E-09	-7.5	-5.5	-3.8	-3.0
215	-1.9E-09	-1.1E-10	-5.0E-10	-7.0E-09	-8.0	-5.4	-4.4	-4.5
216	-1.4E-09	-8.0E-11	-4.2E-10	-6.0E-09	-9.3	-6.1	-5.2	-4.9
217	-2.5E-09	-1.2E-10	-5.0E-10	-7.0E-09	-8.4	-5.2	-4.0	-4.1
218	-4.8E-10	-4.0E-11	-1.9E-10	-2.6E-09	-7.2	-5.7	-3.7	-3.0
219	-5.1E-10	-4.3E-11	-2.0E-10	-2.8E-09	-7.2	-5.7	-3.7	-3.1
220	-1.7E-09	-1.1E-10	-5.0E-10	-6.0E-09	-7.3	-5.3	-4.3	-3.8
221	-4.0E-10	-3.7E-11	-1.8E-10	-2.4E-09	-6.7	-5.6	-3.7	-2.8
222	-3.5E-10	-3.5E-11	-1.7E-10	-2.2E-09	-6.3	-5.5	-3.5	-2.6
223	-6.5E-10	-6.3E-11	-3.0E-10	-4.0E-09	-8.5	-7.2	-5.1	-4.1
224	-4.3E-09	-1.8E-10	-8.0E-10	-9.0E-09	-7.1	-3.7	-3.3	-3.3
225	-5.1E-09	-2.2E-10	-1.1E-09	-1.0E-08	-6.9	-3.7	-3.8	-3.1
226	-5.0E-11	-8.0E-12	-3.0E-11	-6.0E-10	-1.7	-3.2	-1.0	-2.2
227	-3.0E-10	-3.1E-11	-1.6E-10	-2.1E-09	-6.0	-5.1	-3.5	-2.6
228	-1.3E-10	-1.8E-11	-8.0E-11	-1.2E-09	-3.7	-4.5	-2.2	-3.3
229	-3.0E-11	-4.0E-12	-2.0E-11	-3.0E-10	-1.1	-1.8	-0.7	-1.2
230	-2.0E-11	-4.0E-12	-2.0E-11	-3.0E-10	-0.7	-1.8	-0.7	-1.2
231	-3.0E-11	-1.0E-12	-1.0E-11	-2.0E-10	-1.1	-0.5	-0.4	-0.9
232	-6.5E-10	-3.5E-11	-1.7E-10	-2.5E-09	-7.3	-5.5	-3.5	-4.7
233	-7.8E-10	-4.4E-11	-2.2E-10	-3.1E-09	-8.5	-6.3	-4.3	-5.4
234	-2.3E-09	-1.0E-10	-5.0E-10	-6.0E-09	-8.0	-4.9	-4.3	-3.8
235	-1.3E-09	-7.0E-11	-3.3E-10	-5.0E-09	-9.3	-6.9	-5.0	-4.6
236	-8.2E-10	-5.0E-11	-2.4E-10	-3.3E-09	-8.3	-6.0	-4.2	-3.4
237	-6.7E-10	-4.2E-11	-2.0E-10	-2.7E-09	-7.8	-5.5	-3.7	-3.0
238	-7.4E-10	-4.6E-11	-2.3E-10	-3.1E-09	-8.5	-5.9	-4.2	-3.3
239	-2.2E-09	-1.0E-10	-4.0E-10	-5.0E-09	-6.9	-4.7	-3.4	-3.1
240	-1.6E-09	-1.0E-10	-4.5E-10	-5.0E-09	-8.9	-6.9	-5.2	-3.9
241	-4.0E-11	-4.0E-12	-2.0E-11	-4.0E-10	-1.4	-1.9	-0.7	-1.6
242	-1.6E-09	-1.0E-10	-5.0E-10	-6.0E-09	-6.9	-5.0	-4.5	-3.9
243	-2.1E-09	-1.2E-10	-5.0E-10	-7.0E-09	-7.5	-5.0	-3.8	-4.0
244	-3.7E-09	-1.4E-10	-7.0E-10	-7.0E-09	-5.4	-3.0	-3.0	-2.7
245	-4.9E-10	-4.1E-11	-2.0E-10	-2.7E-09	-6.8	-5.5	-3.8	-3.0

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
246	-4.9E-10	-4.2E-11	-2.0E-10	-2.7E-09	-7.4	-6.0	-3.9	-3.1
247	-1.9E-09	-1.1E-10	-5.7E-10	-7.0E-09	-9.0	-6.1	-5.5	-4.8
248	-1.2E-10	-1.5E-11	-7.0E-11	-1.1E-09	-3.4	-4.1	-2.0	-3.2
249	-1.3E-09	-1.1E-10	-5.0E-10	-6.0E-09	-7.7	-5.3	-4.3	-3.8
250	-1.8E-09	-1.2E-10	-6.0E-10	-6.0E-09	-7.0	-4.2	-4.0	-3.2
251	-1.7E-09	-2.9E-11	-1.4E-10	-1.7E-09	-6.9	-3.5	-2.5	-1.9
252	-2.4E-09	-1.0E-10	-5.0E-10	-6.0E-09	-7.9	-5.0	-4.5	-3.9
253	-2.6E-09	-1.2E-10	-5.0E-10	-7.0E-09	-8.4	-5.2	-3.9	-4.0
254	-2.5E-09	-1.2E-10	-6.0E-10	-6.0E-09	-8.3	-5.2	-4.7	-3.5
255	-1.7E-09	-9.0E-11	-4.3E-10	-5.0E-09	-8.6	-5.7	-4.6	-3.7
256	-5.1E-09	-1.8E-10	-8.0E-10	-9.0E-09	-7.0	-3.5	-3.1	-3.2
257	-1.3E-09	-1.7E-10	-8.0E-10	-8.0E-09	-7.9	-4.5	-4.2	-3.7
258	-1.9E-09	-2.6E-11	-1.2E-10	-1.3E-09	-5.8	-2.8	-2.0	-1.4
259	-1.0E-09	-2.1E-11	-1.0E-10	-1.3E-09	-6.1	-3.3	-2.1	-1.6
260	-1.8E-09	-2.4E-11	-1.2E-10	-1.3E-09	-5.3	-2.5	-1.9	-1.4
261	-1.7E-09	-2.7E-11	-1.2E-10	-1.4E-09	-5.6	-2.9	-2.0	-1.5
262	-2.0E-09	-3.4E-11	-1.3E-10	-1.5E-09	-6.0	-3.3	-2.0	-1.6
263	-1.7E-09	-2.7E-11	-1.3E-10	-1.5E-09	-5.7	-2.9	-2.1	-1.6
264	-2.1E-09	-4.0E-11	-1.6E-10	-2.2E-09	-5.8	-3.6	-2.3	-2.2
265	-1.7E-09	-2.7E-11	-1.2E-10	-1.5E-09	-5.7	-2.9	-2.0	-1.6
266	-1.8E-09	-3.0E-11	-1.5E-10	-1.6E-09	-5.8	-2.8	-2.2	-1.6
267	-1.2E-09	-3.0E-11	-1.4E-10	-1.6E-09	-6.2	-3.3	-2.3	-1.7
268	-3.1E-09	-1.1E-10	-5.0E-10	-6.0E-09	-7.9	-4.8	-4.0	-3.5
269	-2.8E-09	-1.0E-10	-5.0E-10	-6.0E-09	-7.7	-4.4	-4.0	-3.5
270	-1.3E-09	-4.0E-11	-1.8E-10	-1.9E-09	-6.3	-3.7	-2.6	-1.9
271	-3.9E-09	-1.2E-10	-6.0E-10	-7.0E-09	-6.8	-3.9	-3.8	-3.5
272	-1.8E-09	-8.0E-11	-3.8E-10	-5.0E-09	-8.0	-5.2	-4.2	-3.8
273	-3.4E-09	-1.2E-10	-5.0E-10	-6.0E-09	-6.9	-4.2	-3.3	-3.1
274	-7.0E-11	-5.0E-12	-3.0E-11	-4.0E-10	-2.3	-2.2	-1.1	-1.6
275	-1.9E-09	-8.0E-11	-3.9E-10	-5.0E-09	-8.8	-5.5	-4.5	-3.8
276	-3.8E-09	-1.2E-10	-6.0E-10	-7.0E-09	-7.1	-4.0	-3.8	-3.5
277	-9.1E-10	-4.9E-11	-2.4E-10	-3.3E-09	-8.7	-5.8	-4.1	-3.4
278	-3.7E-09	-1.2E-10	-6.0E-10	-7.0E-09	-7.1	-4.0	-3.8	-3.5

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
279	-3.9E-09	-1.3E-10	-7.0E-10	-7.0E-09	-7.0	-3.7	-3.9	-3.2
280	-1.0E-10	-9.0E-12	-4.0E-11	-7.0E-10	-3.1	-3.6	-1.4	-2.5
281	-1.4E-09	-7.0E-11	-3.4E-10	-4.0E-09	-8.4	-5.8	-4.5	-3.4
282	-3.6E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.0	-4.3	-3.8	-3.5
283	-6.0E-11	-5.0E-12	-2.0E-11	-4.0E-10	-2.0	-2.3	-0.7	-1.6
284	-2.2E-09	-1.0E-10	-5.0E-10	-6.0E-09	-8.1	-5.1	-4.5	-3.9
285	-3.5E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.0	-4.3	-3.8	-3.5
286	-4.0E-09	-1.4E-10	-6.0E-10	-7.0E-09	-7.2	-4.2	-3.5	-3.3
287	-3.3E-09	-1.3E-10	-6.0E-10	-7.0E-09	-6.9	-4.2	-3.7	-3.4
288	-3.7E-09	-1.4E-10	-7.0E-10	-8.0E-09	-7.0	-4.1	-3.9	-3.6
289	-4.0E-09	-1.5E-10	-7.0E-10	-8.0E-09	-7.2	-4.2	-3.8	-3.5
290	-1.3E-09	-7.0E-11	-3.4E-10	-4.0E-09	-8.2	-5.9	-4.5	-3.4
291	-3.5E-09	-1.2E-10	-6.0E-10	-7.0E-09	-7.2	-4.0	-3.8	-3.5
292	-4.9E-09	-1.5E-10	-7.0E-10	-7.0E-09	-6.2	-3.5	-3.2	-2.8
293	-4.1E-09	-1.3E-10	-6.0E-10	-6.0E-09	-5.9	-3.1	-2.9	-2.5
294	-7.7E-10	-4.5E-11	-2.3E-10	-3.1E-09	-8.2	-6.0	-4.3	-3.4
295	-3.4E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.2	-4.4	-3.8	-3.6
296	-2.9E-09	-1.1E-10	-6.0E-10	-6.0E-09	-7.0	-3.9	-4.0	-3.2
297	-7.2E-10	-4.5E-11	-2.2E-10	-3.0E-09	-8.0	-6.0	-4.1	-3.3
298	-5.9E-10	-3.6E-11	-1.8E-10	-2.4E-09	-7.4	-5.2	-3.6	-2.7
299	-3.3E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.1	-4.4	-3.8	-3.6
300	-3.9E-09	-1.5E-10	-7.0E-10	-8.0E-09	-7.4	-4.2	-3.8	-3.5
301	-1.4E-09	-8.0E-11	-3.9E-10	-5.0E-09	-8.9	-6.0	-4.8	-4.0
302	-2.3E-09	-1.2E-10	-6.0E-10	-7.0E-09	-8.2	-5.5	-4.9	-4.2
303	-1.6E-09	-8.0E-11	-4.1E-10	-5.0E-09	-7.9	-4.7	-4.2	-3.6
304	-1.9E-09	-1.0E-10	-5.0E-10	-6.0E-09	-7.9	-4.9	-4.4	-3.8
305	-3.0E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.4	-4.5	-3.9	-3.6
306	-3.7E-09	-1.5E-10	-7.0E-10	-8.0E-09	-7.5	-4.3	-3.8	-3.6
307	-5.1E-09	-1.7E-10	-8.0E-10	-8.0E-09	-6.3	-3.3	-3.1	-2.8
308	-4.4E-09	-1.5E-10	-7.0E-10	-7.0E-09	-6.6	-3.5	-3.3	-2.9
309	-4.0E-11	-3.0E-12	-2.0E-11	-4.0E-10	-1.4	-1.4	-0.7	-1.6
310	-6.0E-10	-4.1E-11	-2.0E-10	-2.8E-09	-7.8	-5.9	-3.9	-3.2
311	-1.3E-09	-7.0E-11	-3.6E-10	-4.0E-09	-7.5	-5.0	-4.3	-3.2

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
312	-1.3E-09	-7.0E-11	-3.7E-10	-5.0E-09	-8.4	-5.3	-4.6	-4.1
313	-1.5E-09	-8.0E-11	-3.8E-10	-5.0E-09	-7.6	-5.1	-4.1	-3.7
314	-1.4E-09	-8.0E-11	-3.9E-10	-5.0E-09	-7.9	-5.4	-4.4	-3.8
315	-1.5E-09	-9.0E-11	-3.9E-10	-5.0E-09	-7.8	-5.4	-4.0	-3.6
316	-2.9E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.4	-4.5	-3.9	-3.6
317	-5.0E-09	-1.5E-10	-7.0E-10	-7.0E-09	-4.5	-2.2	-2.1	-2.1
318	-2.4E-09	-1.2E-10	-5.0E-10	-7.0E-09	-7.3	-4.4	-3.5	-3.8
319	-2.4E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.5	-4.7	-4.1	-3.8
320	-2.5E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.9	-4.7	-4.1	-3.8
321	-1.7E-09	-4.0E-11	-1.9E-10	-2.0E-09	-5.0	-2.2	-1.9	-1.6
322	-2.1E-09	-1.1E-10	-6.0E-10	-6.0E-09	-7.7	-4.3	-4.3	-3.4
323	-2.3E-09	-1.2E-10	-5.0E-10	-7.0E-09	-7.7	-4.4	-3.5	-3.8
324	-2.0E-11	-2.0E-12	-1.0E-11	-2.0E-10	-0.7	-1.0	-0.4	-0.9
325	-2.3E-09	-1.2E-10	-6.0E-10	-7.0E-09	-7.8	-4.4	-4.2	-3.8
326	-4.7E-09	-1.7E-10	-8.0E-10	-8.0E-09	-6.9	-3.7	-3.5	-3.1
327	-5.0E-09	-1.4E-10	-6.0E-10	-7.0E-09	-4.8	-2.0	-1.9	-2.1
328	-2.1E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.7	-4.9	-4.3	-3.9
329	-2.0E-11	-3.0E-12	-1.0E-11	-3.0E-10	-0.8	-1.5	-0.4	-1.3
330	-2.1E-09	-1.3E-10	-6.0E-10	-7.0E-09	-8.1	-4.9	-4.3	-3.9
331	-2.5E-09	-1.6E-10	-8.0E-10	-8.0E-09	-8.0	-5.0	-4.8	-3.8
332	-4.2E-09	-1.7E-10	-8.0E-10	-9.0E-09	-6.9	-3.8	-3.6	-3.5
333	-4.8E-09	-1.9E-10	-9.0E-10	-9.0E-09	-7.2	-3.8	-3.6	-3.2
334	-3.8E-09	-2.0E-10	-9.0E-10	-1.0E-08	-7.0	-4.0	-3.7	-3.6
335	-3.0E-09	-1.6E-10	-7.0E-10	-7.0E-09	-6.9	-3.8	-3.3	-2.9
336	-6.0E-09	-1.6E-10	-7.0E-10	-7.0E-09	-5.6	-2.4	-2.2	-2.1
337	-3.8E-10	-3.7E-11	-1.8E-10	-2.5E-09	-6.8	-5.9	-3.8	-3.0
338	-6.7E-10	-5.9E-11	-2.8E-10	-4.0E-09	-7.5	-5.7	-4.2	-3.8
339	-2.0E-09	-1.3E-10	-6.0E-10	-7.0E-09	-7.8	-4.9	-4.3	-3.9
340	-3.7E-09	-1.7E-10	-8.0E-10	-8.0E-09	-6.3	-3.4	-3.2	-2.8
341	-2.0E-09	-4.0E-11	-2.0E-10	-1.0E-09	-4.6	-1.6	-1.6	-0.7
342	-1.7E-09	-1.1E-10	-6.0E-10	-6.0E-09	-8.1	-4.5	-4.5	-3.5
343	-4.3E-09	-2.1E-10	-9.0E-10	-1.0E-08	-7.3	-3.9	-3.4	-3.4
344	-3.9E-09	-2.0E-10	-9.0E-10	-9.0E-09	-7.5	-4.2	-3.8	-3.3

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
345	-1.6E-10	-2.0E-11	-1.0E-10	-1.4E-09	-4.1	-4.4	-2.5	-1.9
346	-4.0E-10	-4.6E-11	-2.2E-10	-2.9E-09	-6.7	-5.8	-4.0	-3.2
347	-6.1E-10	-6.0E-11	-3.1E-10	-4.0E-09	-7.3	-5.4	-4.4	-3.6
348	-5.2E-10	-5.6E-11	-2.7E-10	-3.1E-09	-7.3	-5.8	-4.3	-3.1
349	-1.2E-09	-9.0E-11	-4.8E-10	-6.0E-09	-8.9	-5.6	-5.1	-4.4
350	-8.4E-10	-9.0E-11	-3.9E-10	-5.0E-09	-8.1	-6.0	-4.4	-3.9
351	-6.8E-10	-7.0E-11	-3.2E-10	-4.0E-09	-7.6	-5.6	-4.2	-3.5
352	-2.5E-09	-1.7E-10	-8.0E-10	-9.0E-09	-8.4	-5.1	-4.6	-4.2
353	-2.2E-09	-1.4E-10	-7.0E-10	-8.0E-09	-8.8	-5.1	-4.8	-4.3
354	-1.5E-09	-1.1E-10	-6.0E-10	-6.0E-09	-7.5	-4.4	-4.5	-3.5
355	-1.6E-09	-1.2E-10	-6.0E-10	-6.0E-09	-8.1	-4.6	-4.3	-3.4
356	-4.0E-09	-2.2E-10	-1.0E-09	-1.0E-08	-7.6	-4.2	-3.9	-3.5
357	-3.2E-09	-1.7E-10	-8.0E-10	-8.0E-09	-7.4	-4.0	-3.7	-3.3
358	-3.2E-09	-1.8E-10	-8.0E-10	-9.0E-09	-7.4	-4.2	-3.7	-3.7
359	-3.5E-09	-1.9E-10	-9.0E-10	-9.0E-09	-7.4	-4.0	-3.8	-3.4
360	-3.9E-09	-2.2E-10	-1.0E-09	-1.0E-08	-7.5	-4.2	-3.9	-3.5
361	-2.4E-09	-1.6E-10	-7.0E-10	-8.0E-09	-7.6	-4.2	-3.6	-3.6
362	-2.1E-09	-1.4E-10	-6.0E-10	-7.0E-09	-7.4	-3.9	-3.3	-3.3
363	-6.7E-09	-1.6E-10	-7.0E-10	-7.0E-09	-6.3	-2.0	-1.8	-1.9
364	-8.3E-10	-8.0E-11	-3.8E-10	-5.0E-09	-8.0	-5.3	-4.3	-3.9
365	-4.0E-09	-2.2E-10	-1.0E-09	-1.0E-08	-7.6	-4.2	-3.9	-3.5
366	-8.0E-10	-8.0E-11	-4.1E-10	-5.0E-09	-8.0	-5.3	-4.6	-3.9
367	-1.3E-09	-1.1E-10	-5.0E-10	-6.0E-09	-8.5	-4.9	-4.1	-3.8
368	-1.3E-09	-1.2E-10	-6.0E-10	-6.0E-09	-7.8	-4.9	-4.5	-3.5
369	-1.0E-09	-9.0E-11	-5.0E-10	-5.0E-09	-7.4	-4.3	-4.3	-3.3
370	-1.1E-09	-1.1E-10	-6.0E-10	-6.0E-09	-7.4	-4.8	-4.8	-3.7
371	-1.2E-10	-1.8E-11	-9.0E-11	-1.3E-09	-3.5	-4.2	-2.4	-1.9
372	-1.8E-09	-1.5E-10	-7.0E-10	-7.0E-09	-7.9	-4.3	-3.9	-3.4
373	-4.9E-10	-6.1E-11	-2.9E-10	-4.2E-09	-7.4	-6.2	-4.5	-4.1
374	-1.7E-09	-1.5E-10	-6.0E-10	-7.0E-09	-7.0	-4.1	-3.3	-3.3
375	-2.4E-09	-1.9E-10	-9.0E-10	-9.0E-09	-8.1	-4.5	-4.2	-3.7
376	-3.1E-09	-2.6E-10	-1.2E-09	-1.2E-08	-8.3	-4.8	-4.5	-4.0
377	-2.3E-09	-1.9E-10	-9.0E-10	-9.0E-09	-8.1	-4.5	-4.3	-3.7

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
378	-1.3E-09	-1.5E-10	-7.0E-10	-7.0E-09	-7.8	-4.7	-4.3	-3.6
379	-8.3E-10	-1.2E-10	-6.0E-10	-6.0E-09	-7.7	-4.4	-4.2	-3.5
380	-9.0E-10	-1.5E-10	-7.0E-10	-7.0E-09	-7.5	-5.0	-4.5	-3.8
381	-8.8E-10	-1.6E-10	-8.0E-10	-8.0E-09	-8.2	-5.1	-4.9	-4.2
382	-2.2E-09	-3.0E-11	-1.2E-10	-1.3E-09	-5.2	-2.6	-1.7	-1.4
383	-2.1E-09	-2.0E-11	-1.2E-10	-1.4E-09	-5.3	-1.7	-1.7	-1.5
384	-2.1E-09	-3.0E-11	-1.4E-10	-1.6E-09	-5.0	-2.2	-1.7	-1.6
385	-1.9E-09	-2.0E-11	-1.3E-10	-1.4E-09	-4.9	-1.7	-1.8	-1.5
386	-2.1E-09	-3.0E-11	-1.4E-10	-1.5E-09	-4.9	-2.3	-1.8	-1.5
387	-1.9E-10	-9.0E-12	-4.0E-11	-8.0E-10	-4.8	-3.7	-1.4	-4.1
388	-4.8E-09	-1.4E-10	-6.0E-10	-7.0E-09	-5.9	-3.2	-2.7	-2.8
389	-7.0E-11	-6.0E-12	-2.0E-11	-5.0E-10	-2.3	-2.8	-0.7	-3.0
390	-8.0E-11	-5.0E-12	-3.0E-11	-6.0E-10	-2.6	-2.3	-1.1	-3.5
391	-4.5E-09	-1.4E-10	-6.0E-10	-6.0E-09	-6.2	-3.4	-2.9	-2.6
392	-4.0E-09	-1.3E-10	-6.0E-10	-6.0E-09	-6.2	-3.3	-3.0	-2.7
393	-2.4E-09	-1.2E-10	-5.0E-10	-7.0E-09	-8.3	-5.7	-4.3	-4.5
394	-3.8E-09	-1.6E-10	-7.0E-10	-8.0E-09	-7.4	-4.7	-4.0	-3.8
395	-4.5E-09	-1.5E-10	-6.0E-10	-7.0E-09	-6.4	-3.6	-2.9	-3.0
396	-4.9E-09	-1.5E-10	-7.0E-10	-8.0E-09	-6.3	-3.3	-3.1	-3.2
397	-1.8E-09	-9.0E-11	-4.2E-10	-5.0E-09	-7.9	-5.3	-4.3	-3.8
398	-4.3E-09	-1.4E-10	-7.0E-10	-7.0E-09	-6.3	-3.4	-3.4	-3.0
399	-4.3E-09	-1.5E-10	-6.0E-10	-7.0E-09	-6.5	-3.7	-2.9	-3.0
400	-4.7E-09	-1.8E-10	-8.0E-10	-8.0E-09	-6.7	-3.7	-3.3	-3.0
401	-1.5E-09	-9.0E-11	-4.0E-10	-5.0E-09	-7.4	-5.4	-4.1	-3.8
402	-3.7E-09	-1.7E-10	-7.0E-10	-8.0E-09	-7.2	-4.1	-3.3	-3.4
403	-1.4E-09	-1.0E-10	-5.0E-10	-5.0E-09	-7.4	-4.5	-4.1	-3.3
404	-1.6E-09	-1.1E-10	-5.0E-10	-7.0E-09	-7.7	-4.5	-3.8	-4.3
405	-4.1E-09	-1.8E-10	-8.0E-10	-9.0E-09	-7.3	-3.9	-3.5	-3.5
406	-2.7E-09	-1.8E-10	-8.0E-10	-8.0E-09	-7.5	-4.6	-4.0	-3.6
407	-3.0E-09	-1.9E-10	-9.0E-10	-1.0E-08	-7.6	-4.4	-4.1	-4.1
408	-2.4E-09	-1.7E-10	-8.0E-10	-8.0E-09	-7.5	-4.0	-3.8	-3.4
409	-1.9E-09	-1.5E-10	-7.0E-10	-8.0E-09	-7.2	-4.3	-4.0	-4.0
410	-7.2E-10	-8.0E-11	-3.6E-10	-5.0E-09	-7.8	-5.7	-4.3	-4.4

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
411	-2.1E-09	-1.6E-10	-7.0E-10	-9.0E-09	-8.6	-5.4	-4.5	-4.7
412	-3.4E-09	-2.0E-10	-9.0E-10	-1.0E-08	-7.8	-4.2	-3.8	-3.8
413	-4.5E-09	-2.7E-10	-1.3E-09	-1.4E-08	-7.7	-4.2	-4.1	-4.1
414	-1.9E-09	-1.4E-10	-6.0E-10	-7.0E-09	-6.5	-3.9	-3.3	-3.4
415	-2.0E-09	-1.5E-10	-7.0E-10	-8.0E-09	-7.5	-4.3	-4.0	-4.0
416	-2.1E-09	-1.4E-10	-7.0E-10	-7.0E-09	-7.9	-4.0	-3.9	-3.5
417	-2.2E-09	-1.6E-10	-8.0E-10	-8.0E-09	-7.5	-4.2	-4.1	-3.7
418	-2.5E-09	-1.7E-10	-8.0E-10	-9.0E-09	-7.8	-4.0	-3.8	-3.8
419	-2.1E-09	-1.6E-10	-8.0E-10	-9.0E-09	-7.4	-4.0	-4.0	-4.0
420	-1.8E-09	-1.4E-10	-7.0E-10	-7.0E-09	-7.9	-4.2	-4.1	-3.6
421	-1.1E-09	-1.1E-10	-5.0E-10	-6.0E-09	-8.0	-5.1	-4.2	-4.1
422	-1.5E-09	-1.3E-10	-6.0E-10	-7.0E-09	-8.1	-4.2	-3.7	-3.8
423	-2.9E-09	-2.0E-10	-9.0E-10	-9.0E-09	-6.7	-3.3	-3.1	-3.1
424	-1.7E-09	-3.0E-11	-1.2E-10	-2.0E-09	-4.3	-2.6	-1.7	-0.8
425	-1.6E-09	-2.0E-11	-1.2E-10	-1.0E-09	-4.4	-1.7	-1.7	-0.4
426	-1.7E-09	-3.0E-11	-1.3E-10	-1.0E-09	-5.2	-2.7	-1.9	-0.4
427	-1.9E-09	-2.0E-11	-1.2E-10	-1.0E-09	-4.0	-1.3	-1.4	-0.4
428	-7.0E-10	-1.9E-11	-9.0E-11	-2.0E-09	-5.8	-3.5	-2.1	-0.9
429	-1.6E-09	-2.0E-11	-1.3E-10	-1.0E-09	-4.5	-1.7	-1.8	-0.4
430	-2.1E-09	-3.0E-11	-1.7E-10	-2.0E-09	-5.3	-2.2	-2.1	-0.8
431	-1.5E-10	-8.0E-12	-4.0E-11	0.0E+00	-4.2	-3.3	-1.4	0.0
432	-1.6E-09	-3.0E-11	-1.2E-10	-1.0E-09	-4.6	-2.6	-1.7	-0.4
433	-4.8E-09	-1.3E-10	-5.0E-10	-6.0E-09	-5.4	-3.2	-2.5	-1.6
434	-4.5E-09	-1.3E-10	-6.0E-10	-6.0E-09	-5.1	-3.2	-2.9	-1.6
435	-4.6E-09	-1.2E-10	-6.0E-10	-6.0E-09	-5.3	-3.0	-3.0	-1.6
436	-5.0E-09	-1.4E-10	-7.0E-10	-8.0E-09	-6.3	-3.1	-3.1	-2.0
437	-5.4E-09	-1.6E-10	-8.0E-10	-8.0E-09	-6.4	-3.4	-3.4	-1.9
438	-4.7E-09	-1.5E-10	-7.0E-10	-8.0E-09	-6.4	-3.3	-3.1	-2.0
439	-4.0E-09	-1.3E-10	-6.0E-10	-7.0E-09	-5.6	-3.3	-3.0	-1.8
440	-3.8E-09	-1.2E-10	-5.0E-10	-6.0E-09	-5.4	-3.0	-2.5	-1.6
441	-3.9E-09	-1.3E-10	-7.0E-10	-6.0E-09	-5.9	-3.3	-3.5	-1.6
442	-4.8E-09	-1.6E-10	-8.0E-10	-9.0E-09	-6.0	-3.3	-3.3	-2.1
443	-4.2E-09	-1.6E-10	-8.0E-10	-8.0E-09	-6.5	-3.6	-3.6	-2.0

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
444	-3.9E-09	-1.4E-10	-6.0E-10	-7.0E-09	-6.0	-3.6	-3.0	-1.9
445	-3.0E-09	-1.4E-10	-7.0E-10	-7.0E-09	-6.6	-4.5	-4.2	-2.0
446	-3.7E-09	-1.3E-10	-7.0E-10	-6.0E-09	-5.9	-3.3	-3.5	-1.6
447	-2.6E-09	-1.2E-10	-6.0E-10	-6.0E-09	-8.0	-4.9	-4.5	-1.9
448	-3.4E-09	-1.3E-10	-6.0E-10	-6.0E-09	-5.5	-3.3	-3.0	-1.6
449	-3.6E-09	-1.4E-10	-6.0E-10	-8.0E-09	-6.5	-3.7	-3.1	-2.2
450	-4.5E-09	-1.7E-10	-7.0E-10	-8.0E-09	-6.8	-3.7	-3.1	-2.0
451	-3.3E-09	-1.3E-10	-6.0E-10	-8.0E-09	-7.6	-4.7	-4.1	-2.4
452	-3.4E-09	-1.3E-10	-6.0E-10	-7.0E-09	-5.8	-3.4	-3.0	-1.9
453	-4.4E-09	-1.8E-10	-8.0E-10	-9.0E-09	-6.8	-3.9	-3.5	-2.2
454	-1.0E-09	-6.0E-11	-3.2E-10	-4.0E-09	-7.1	-4.9	-4.2	-1.5
455	-3.5E-09	-1.4E-10	-6.0E-10	-8.0E-09	-7.0	-3.8	-3.2	-2.2
456	-4.9E-09	-1.5E-10	-7.0E-10	-8.0E-09	-6.9	-3.5	-3.2	-2.0
457	-2.6E-09	-1.4E-10	-6.0E-10	-8.0E-09	-7.1	-4.7	-3.8	-2.3
458	-3.8E-09	-1.7E-10	-7.0E-10	-9.0E-09	-6.0	-3.7	-3.0	-2.2
459	-3.0E-09	-1.4E-10	-6.0E-10	-7.0E-09	-5.9	-3.7	-3.1	-1.9
460	-9.0E-10	-6.0E-11	-3.0E-10	-4.0E-09	-7.2	-5.1	-4.1	-1.6
461	-1.7E-09	-1.0E-10	-5.0E-10	-5.0E-09	-7.4	-4.6	-4.2	-1.7
462	-3.0E-09	-1.4E-10	-6.0E-10	-7.0E-09	-6.0	-3.7	-3.1	-1.9
463	-3.2E-09	-1.4E-10	-6.0E-10	-8.0E-09	-7.1	-3.8	-3.2	-2.2
464	-4.5E-09	-1.5E-10	-6.0E-10	-7.0E-09	-5.6	-2.5	-2.1	-1.6
465	-6.8E-10	-6.0E-11	-2.7E-10	-4.0E-09	-6.9	-5.6	-3.9	-1.6
466	-2.5E-09	-1.4E-10	-6.0E-10	-7.0E-09	-6.2	-3.8	-3.2	-1.9
467	-4.2E-09	-1.9E-10	-1.0E-09	-1.0E-08	-7.5	-4.1	-4.3	-2.4
468	-2.4E-09	-1.3E-10	-6.0E-10	-7.0E-09	-6.4	-3.6	-3.3	-1.9
469	-2.4E-09	-1.3E-10	-6.0E-10	-7.0E-09	-6.5	-3.6	-3.3	-1.9
470	-2.2E-09	-1.3E-10	-6.0E-10	-7.0E-09	-6.4	-3.7	-3.3	-2.0
471	-7.0E-09	-1.0E-10	-4.0E-10	-4.0E-09	-3.7	-0.9	-0.8	-0.5
472	-2.2E-09	-1.4E-10	-6.0E-10	-6.0E-09	-6.6	-4.0	-3.4	-1.7
473	-3.5E-09	-2.2E-10	-1.1E-09	-1.2E-08	-6.5	-3.8	-3.9	-2.6
474	-3.4E-09	-1.6E-10	-7.0E-10	-7.0E-09	-4.9	-2.6	-2.4	-1.6
475	-7.0E-09	-1.2E-10	-6.0E-10	-5.0E-09	-5.0	-1.3	-1.4	-0.6
476	-4.8E-09	-1.5E-10	-7.0E-10	-6.0E-09	-4.9	-1.7	-1.7	-0.8

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
477	-6.0E-09	-2.0E-10	-9.0E-10	-7.0E-09	-5.0	-1.9	-1.8	-0.8
478	-9.0E-10	-8.0E-11	-3.8E-10	-4.0E-09	-7.7	-5.5	-4.4	-1.5
479	-1.5E-09	-1.1E-10	-5.0E-10	-6.0E-09	-7.4	-4.7	-3.9	-1.9
480	-1.2E-09	-9.0E-11	-4.0E-10	-5.0E-09	-8.1	-4.7	-3.7	-1.7
481	-2.1E-09	-1.3E-10	-7.0E-10	-7.0E-09	-6.4	-3.7	-3.9	-2.0
482	-2.6E-09	-1.6E-10	-8.0E-10	-8.0E-09	-6.6	-3.8	-3.8	-2.1
483	-2.5E-09	-1.6E-10	-7.0E-10	-8.0E-09	-7.6	-4.3	-3.7	-2.2
484	-3.5E-09	-1.7E-10	-8.0E-10	-8.0E-09	-6.2	-2.9	-2.9	-1.8
485	-7.0E-09	-1.8E-10	-8.0E-10	-8.0E-09	-5.6	-2.1	-2.0	-1.5
486	-1.9E-09	-1.4E-10	-6.0E-10	-7.0E-09	-6.6	-4.1	-3.4	-2.0
487	-5.0E-09	-1.4E-10	-6.0E-10	-6.0E-09	-4.1	-1.5	-1.4	-0.7
488	-1.8E-09	-1.3E-10	-7.0E-10	-7.0E-09	-6.7	-3.9	-4.1	-2.0
489	-1.7E-09	-1.3E-10	-6.0E-10	-7.0E-09	-6.8	-4.0	-3.6	-2.0
490	-2.7E-09	-2.0E-10	-9.0E-10	-1.0E-08	-7.9	-4.7	-4.2	-2.6
491	-2.2E-09	-1.5E-10	-7.0E-10	-8.0E-09	-7.8	-4.3	-3.9	-2.3
492	-2.5E-09	-1.7E-10	-9.0E-10	-9.0E-09	-8.0	-4.5	-4.6	-2.4
493	-2.7E-09	-1.9E-10	-9.0E-10	-1.0E-08	-7.9	-4.5	-4.2	-2.6
494	-1.6E-09	-1.3E-10	-6.0E-10	-6.0E-09	-6.9	-4.1	-3.6	-1.8
495	-1.7E-09	-1.4E-10	-6.0E-10	-7.0E-09	-8.1	-4.6	-3.8	-2.1
496	-1.7E-09	-1.4E-10	-7.0E-10	-7.0E-09	-7.4	-4.2	-4.0	-2.0
497	-4.3E-09	-2.1E-10	-1.0E-09	-9.0E-09	-6.4	-3.0	-3.0	-1.9
498	-3.0E-09	-1.7E-10	-8.0E-10	-8.0E-09	-6.0	-2.8	-2.8	-1.8
499	-6.0E-09	-1.6E-10	-7.0E-10	-6.0E-09	-5.7	-1.7	-1.6	-0.7
500	-6.0E-09	-2.0E-10	-8.0E-10	-7.0E-09	-5.1	-1.9	-1.7	-0.8
501	-2.0E-09	-1.7E-10	-8.0E-10	-8.0E-09	-7.9	-4.6	-4.2	-2.2
502	-1.7E-09	-1.5E-10	-7.0E-10	-7.0E-09	-7.5	-4.3	-3.9	-2.0
503	-6.0E-09	-2.0E-10	-9.0E-10	-8.0E-09	-4.7	-1.8	-1.7	-0.9
504	-1.4E-09	-1.3E-10	-5.0E-10	-6.0E-09	-7.1	-4.3	-3.2	-1.8
505	-1.4E-09	-1.2E-10	-6.0E-10	-6.0E-09	-7.7	-4.1	-3.9	-1.8
506	-4.8E-09	-1.5E-10	-7.0E-10	-7.0E-09	-5.1	-1.6	-1.6	-0.9
507	-1.5E-09	-1.4E-10	-6.0E-10	-7.0E-09	-7.7	-4.4	-3.6	-2.1
508	-2.6E-09	-1.8E-10	-8.0E-10	-8.0E-09	-5.5	-2.6	-2.4	-1.7
509	-4.3E-09	-1.7E-10	-8.0E-10	-7.0E-09	-5.4	-1.8	-1.9	-0.9

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
510	-1.0E-09	-1.2E-10	-6.0E-10	-6.0E-09	-6.4	-3.9	-3.8	-1.8
511	-9.0E-10	-1.1E-10	-5.0E-10	-6.0E-09	-6.4	-4.0	-3.5	-1.9
512	-1.3E-09	-1.3E-10	-7.0E-10	-7.0E-09	-7.8	-4.3	-4.5	-2.1
513	-4.1E-09	-1.0E-10	-4.0E-10	-5.0E-09	-6.2	-3.9	-2.9	-1.5
514	-1.3E-09	-3.0E-11	-1.3E-10	-1.0E-09	-4.5	-2.8	-1.9	-0.4
515	-1.8E-09	-3.0E-11	-1.2E-10	-1.0E-09	-3.8	-2.0	-1.4	-0.4
516	-2.3E-09	-1.0E-11	0.0E+00	0.0E+00	-2.8	-0.4	0.0	0.0
517	-4.0E-09	-1.0E-10	-5.0E-10	-6.0E-09	-6.2	-3.9	-3.6	-1.8
518	-5.0E-09	-1.2E-10	-6.0E-10	-7.0E-09	-6.3	-3.8	-3.6	-2.0
519	-5.6E-09	-1.3E-10	-6.0E-10	-7.0E-09	-5.5	-3.0	-2.8	-1.8
520	-1.8E-09	-3.0E-11	-1.2E-10	-1.0E-09	-3.8	-2.0	-1.4	-0.4
521	-1.8E-09	-2.0E-11	-1.1E-10	-2.0E-09	-3.6	-1.3	-1.2	-0.8
522	-4.1E-09	-1.1E-10	-5.0E-10	-7.0E-09	-7.1	-4.4	-3.7	-2.2
523	-1.7E-09	-2.0E-11	-1.2E-10	-1.0E-09	-3.6	-1.3	-1.4	-0.4
524	-1.9E-09	-3.0E-11	-1.3E-10	-1.0E-09	-4.4	-2.0	-1.5	-0.4
525	-2.3E-09	-2.0E-11	0.0E+00	-1.0E-09	-3.3	-1.0	0.0	-0.2
526	-5.0E-09	-1.2E-10	-5.0E-10	-6.0E-09	-4.0	-2.2	-1.8	-1.4
527	-6.0E-09	-1.2E-10	-6.0E-10	-6.0E-09	-5.0	-2.2	-2.2	-1.4
528	-3.2E-09	-1.3E-10	-7.0E-10	-8.0E-09	-7.1	-4.6	-4.6	-2.3
529	-6.0E-09	-1.6E-10	-7.0E-10	-8.0E-09	-4.7	-2.4	-2.2	-1.6
530	-2.4E-09	-1.0E-10	-5.0E-10	-6.0E-09	-7.0	-4.3	-3.9	-1.9
531	-3.5E-09	-1.4E-10	-7.0E-10	-7.0E-09	-6.7	-3.8	-3.7	-1.9
532	-5.0E-09	-1.3E-10	-6.0E-10	-6.0E-09	-4.3	-2.2	-2.1	-1.4
533	-8.0E-09	-1.1E-10	-5.0E-10	-5.0E-09	-4.7	-1.5	-1.5	-1.0
534	-4.2E-09	-1.4E-10	-6.0E-10	-6.0E-09	-4.2	-2.5	-2.2	-1.4
535	-3.1E-09	-1.5E-10	-7.0E-10	-9.0E-09	-8.1	-4.8	-4.2	-2.5
536	-1.9E-09	-1.0E-10	-4.0E-10	-6.0E-09	-6.8	-4.6	-3.3	-2.0
537	-2.1E-09	-1.1E-10	-5.0E-10	-6.0E-09	-6.9	-4.6	-3.8	-1.9
538	-2.4E-09	-1.3E-10	-6.0E-10	-6.0E-09	-7.1	-4.9	-4.2	-1.8
539	-2.9E-09	-1.4E-10	-7.0E-10	-7.0E-09	-6.8	-4.0	-3.9	-1.9
540	-4.6E-09	-1.5E-10	-7.0E-10	-7.0E-09	-4.6	-2.4	-2.3	-1.5
541	-5.3E-09	-1.8E-10	-9.0E-10	-9.0E-09	-5.9	-2.8	-2.9	-1.9
542	-7.0E-09	-1.1E-10	-7.0E-10	-7.0E-09	-4.2	-1.1	-1.5	-0.8

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
543	-1.9E-09	-9.0E-11	-4.0E-10	-6.0E-09	-7.1	-4.1	-3.3	-2.0
544	-4.3E-09	-1.4E-10	-6.0E-10	-7.0E-09	-4.9	-2.5	-2.2	-1.6
545	-4.7E-09	-1.5E-10	-7.0E-10	-7.0E-09	-4.8	-2.4	-2.3	-1.5
546	-3.5E-09	-1.6E-10	-8.0E-10	-8.0E-09	-6.9	-4.0	-3.9	-2.1
547	-4.1E-09	-1.5E-10	-7.0E-10	-7.0E-09	-4.8	-2.7	-2.6	-1.6
548	-3.2E-09	-1.6E-10	-7.0E-10	-8.0E-09	-7.3	-4.1	-3.5	-2.1
549	-2.8E-09	-1.4E-10	-7.0E-10	-7.0E-09	-7.4	-4.0	-3.9	-1.9
550	-2.2E-09	-1.2E-10	-5.0E-10	-6.0E-09	-7.2	-4.0	-3.2	-1.8
551	-3.8E-09	-1.5E-10	-7.0E-10	-7.0E-09	-5.2	-2.7	-2.6	-1.6
552	-5.0E-09	-1.2E-10	-5.0E-10	-5.0E-09	-3.8	-1.3	-1.2	-0.6
553	-1.2E-09	-9.0E-11	-4.0E-10	-5.0E-09	-7.1	-4.8	-3.7	-1.7
554	-4.8E-09	-2.0E-10	-9.0E-10	-9.0E-09	-5.7	-2.5	-2.4	-1.7
555	-1.2E-09	-9.0E-11	-4.0E-10	-5.0E-09	-7.1	-4.8	-3.7	-1.7
556	-3.3E-09	-1.5E-10	-7.0E-10	-7.0E-09	-5.5	-2.8	-2.7	-1.6
557	-2.8E-09	-1.6E-10	-7.0E-10	-8.0E-09	-5.6	-3.0	-2.7	-1.9
558	-3.1E-09	-1.7E-10	-7.0E-10	-8.0E-09	-6.7	-3.3	-2.8	-1.9
559	-5.0E-09	-1.5E-10	-6.0E-10	-6.0E-09	-4.3	-1.7	-1.5	-0.7
560	-6.0E-09	-1.2E-10	-5.0E-10	-5.0E-09	-4.5	-1.2	-1.1	-0.6
561	-7.0E-09	-2.0E-10	-7.0E-10	-5.0E-09	-4.7	-1.9	-1.4	-0.6
562	-6.0E-09	-1.0E-10	-4.0E-10	-4.0E-09	-3.9	-0.9	-0.8	-0.5
563	-9.0E-09	-1.0E-10	-6.0E-10	-5.0E-09	-4.3	-0.7	-0.9	-0.5
564	-2.9E-09	-1.6E-10	-7.0E-10	-7.0E-09	-5.8	-3.0	-2.7	-1.7
565	-5.3E-09	-1.8E-10	-8.0E-10	-8.0E-09	-5.3	-2.2	-2.1	-1.5
566	-1.1E-09	-1.1E-10	-5.0E-10	-6.0E-09	-6.4	-4.1	-3.5	-1.9
567	-3.0E-09	-1.8E-10	-9.0E-10	-8.0E-09	-6.9	-3.4	-3.5	-1.9
568	-3.3E-09	-2.0E-10	-9.0E-10	-1.0E-08	-6.9	-3.4	-3.2	-2.2
569	-3.7E-09	-2.2E-10	-1.0E-09	-1.0E-08	-7.0	-3.4	-3.2	-2.1
570	-7.0E-09	-3.0E-10	-1.0E-09	-9.0E-09	-6.5	-2.8	-2.0	-1.0
571	-1.4E-09	-1.3E-10	-7.0E-10	-7.0E-09	-7.8	-4.6	-4.7	-2.2
572	-3.5E-10	-6.0E-11	-3.0E-10	-4.0E-09	-6.0	-3.4	-3.0	-1.5
573	-6.2E-09	-1.2E-10	-6.0E-10	-7.0E-09	-6.8	-3.6	-3.4	-1.1
574	-2.6E-09	-2.0E-11	-1.0E-10	-1.0E-09	-3.8	-1.0	-1.0	-0.1
575	-7.0E-09	-1.3E-10	-6.0E-10	-7.0E-09	-5.8	-3.1	-2.9	-1.0

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
576	-2.6E-09	-1.0E-11	-1.0E-10	-1.0E-09	-3.8	-0.5	-1.0	-0.1
577	-8.0E-09	-1.0E-10	-4.0E-10	0.0E+00	-4.2	-1.3	-1.1	0.0
578	-5.6E-09	-1.8E-10	-8.0E-10	-1.0E-08	-6.8	-3.7	-3.3	-1.4
579	-1.3E-09	-8.0E-11	-4.2E-10	-5.0E-09	-8.0	-4.9	-4.4	-0.9
580	-1.2E-09	-1.3E-10	-6.0E-10	-7.0E-09	-6.2	-3.7	-3.3	-1.1
581	-1.1E-09	-1.0E-10	-5.0E-10	-5.0E-09	-6.7	-3.5	-3.3	-0.8
582	-1.2E-09	-1.1E-10	-5.0E-10	-6.0E-09	-6.7	-3.5	-3.0	-0.9
583	-1.0E-09	-1.1E-10	-5.0E-10	-5.0E-09	-7.1	-3.8	-3.3	-0.8
584	-6.3E-09	-2.6E-10	-1.2E-09	-1.4E-08	-6.5	-3.3	-3.2	-1.6

14 Appendix 4 Non-natural gas failure rates

This section contains the detailed non-natural gas pipeline results. Those obtained using version 3.04 of PIPIN can be found in Section 14.1, those using the new version, 3.1, can be found in 14.2 and a comparison of the two sets of results can be found in Section 14.3.

14.1 V3.04 of PIPIN

Table 18 Failure rates for non-natural gas pipelines calculated using V3.04 of PIPIN

Pipeline	Substance	Rupture	Large hole	Small hole	Pinhole
9669	Ethylene	5.68E-08	1.19E-09	7.17E-09	9.84E-08
11906	Propane	1.33E-08	7.87E-09	1.89E-08	1.93E-07
11885	N-butane	3.11E-08	9.94E-09	2.84E-08	2.91E-07
11886	Propane	2.36E-08	9.24E-09	2.53E-08	2.59E-07
7129	Ethylene	9.71E-08	1.77E-09	9.70E-09	1.09E-07
10021	Ethylene	1.45E-08	7.35E-10	5.24E-09	2.28E-07
6799	Propylene	1.10E-07	1.19E-08	3.76E-08	3.89E-07
7335	Ethylene	8.70E-09	4.03E-10	3.71E-09	1.81E-07
12855	Ethylene	2.01E-08	5.84E-10	4.51E-09	2.19E-07
6978	Propane	2.03E-08	8.95E-09	2.39E-08	2.42E-07
12592	Propane	5.65E-08	1.43E-08	4.76E-08	4.47E-07
6713	Ethylene	5.68E-09	2.73E-10	3.03E-09	2.02E-07
8395	Propane	2.02E-08	1.03E-08	2.98E-08	2.95E-07
6904	Ethylene	2.29E-08	6.16E-10	4.64E-09	6.79E-08
7338	Propane	2.17E-08	7.79E-09	1.84E-08	1.80E-07
7340	N-butane	2.17E-08	7.79E-09	1.84E-08	1.80E-07
6802	Ethylene	2.05E-08	7.29E-10	5.21E-09	2.28E-07

14.2 V3.1 of PIPIN

Table 19 Non-natural gas failure rates using V3.1 of PIPIN

Pipeline	Substance	Rupture	Large hole	Small hole	Pinhole
9669	Ethylene	5.43E-08	1.17E-09	7.08E-09	9.75E-08
11906	Propane	1.32E-08	7.86E-09	1.88E-08	1.92E-07
11885	N-butane	2.93E-08	9.79E-09	2.77E-08	2.83E-07
11886	Propane	2.24E-08	9.13E-09	2.47E-08	2.52E-07
7129	Ethylene	9.35E-08	1.76E-09	9.62E-09	1.08E-07
10021	Ethylene	1.37E-08	7.06E-10	5.10E-09	2.26E-07
6799	Propylene	1.05E-07	1.18E-08	3.69E-08	3.80E-07
7335	Ethylene	8.04E-09	3.83E-10	3.61E-09	1.79E-07
12855	Ethylene	1.89E-08	5.66E-10	4.42E-09	2.18E-07
6978	Propane	1.95E-08	8.87E-09	2.35E-08	2.38E-07
12592	Propane	5.38E-08	1.41E-08	4.68E-08	4.39E-07
6713	Ethylene	5.39E-09	2.66E-10	3.00E-09	2.02E-07
8395	Propane	1.95E-08	1.02E-08	2.94E-08	2.91E-07
6904	Ethylene	2.18E-08	6.02E-10	4.57E-09	6.71E-08
7338	Propane	2.10E-08	7.77E-09	1.83E-08	1.78E-07
7340	N-butane	2.10E-08	7.77E-09	1.83E-08	1.78E-07
6802	Ethylene	1.93E-08	7.02E-10	5.08E-09	2.26E-07

14.3 Comparison

In the subsequent table, the differences are the 3.1 PIPIN failure rates– the 3.04 PIPIN failure rates. The percentages are then calculated using the equation (3.1 PIPIN failure rates – 3.04 PIPIN failure rates)/3.1 PIPIN failure rates.

Table 20 Comparison of the non-natural gas failure rates using versions 3.04 and 3.1 of PIPIN

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
9669	-2.50E-09	-2.00E-11	-9.00E-11	-9.00E-10	-4.4	-1.7	-1.3	-0.9
11906	-1.00E-10	-1.00E-11	-1.00E-10	-1.00E-09	-0.8	-0.1	-0.5	-0.5
11885	-1.80E-09	-1.50E-10	-7.00E-10	-8.00E-09	-5.8	-1.5	-2.5	-2.7
11886	-1.20E-09	-1.10E-10	-6.00E-10	-7.00E-09	-5.1	-1.2	-2.4	-2.7
7129	-3.60E-09	-1.00E-11	-8.00E-11	-1.00E-09	-3.7	-0.6	-0.8	-0.9
10021	-8.00E-10	-2.90E-11	-1.40E-10	-2.00E-09	-5.5	-3.9	-2.7	-0.9
6799	-5.00E-09	-1.00E-10	-7.00E-10	-9.00E-09	-4.5	-0.8	-1.9	-2.3
7335	-6.60E-10	-2.00E-11	-1.00E-10	-2.00E-09	-7.6	-5.0	-2.7	-1.1
12855	-1.20E-09	-1.80E-11	-9.00E-11	-1.00E-09	-6.0	-3.1	-2.0	-0.5
6978	-8.00E-10	-8.00E-11	-4.00E-10	-4.00E-09	-3.9	-0.9	-1.7	-1.7
12592	-2.70E-09	-2.00E-10	-8.00E-10	-8.00E-09	-4.8	-1.4	-1.7	-1.8
6713	-2.90E-10	-7.00E-12	-3.00E-11	0.00E00	-5.1	-2.6	-1.0	0.0
8395	-7.00E-10	-1.00E-10	-4.00E-10	-4.00E-09	-3.5	-1.0	-1.3	-1.4
6904	-1.10E-09	-1.40E-11	-7.00E-11	-8.00E-10	-4.8	-2.3	-1.5	-1.2
7338	-7.00E-10	-2.00E-11	-1.00E-10	-2.00E-09	-3.2	-0.3	-0.5	-1.1
7340	-7.00E-10	-2.00E-11	-1.00E-10	-2.00E-09	-3.2	-0.3	-0.5	-1.1
6802	-1.20E-09	-2.70E-11	-1.30E-10	-2.00E-09	-5.9	-3.7	-2.5	-0.9

15 Appendix 5 Hydrogen failure rates calculated by V3.1 PIPIN

This section contains the failure rates calculated by V3.1 of PIPIN (Section 15.1) and a comparison of these failure rates with those for methane (Section 15.2).

15.1 Calculated failure rates

Table 21 Hydrogen failure rates using V3.1 of PIPIN

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
1	2.63E-09	1.73E-10	2.54E-09	2.11E-08
2	3.47E-09	1.84E-10	2.59E-09	2.20E-08
3	3.98E-09	1.89E-10	2.62E-09	2.25E-08
4	4.79E-09	1.98E-10	2.66E-09	2.31E-08
5	3.16E-09	1.85E-10	2.60E-09	2.22E-08
6	3.85E-09	1.90E-10	2.62E-09	2.25E-08
7	4.33E-09	2.07E-10	2.71E-09	2.38E-08
8	5.70E-09	2.55E-10	2.95E-09	2.71E-08
9	2.81E-09	1.89E-10	2.62E-09	2.27E-08
10	5.61E-09	2.17E-10	2.76E-09	2.47E-08
11	5.03E-09	2.14E-10	2.74E-09	2.44E-08
12	4.60E-09	2.11E-10	2.73E-09	2.42E-08
13	4.19E-09	2.04E-10	2.70E-09	2.37E-08
14	2.70E-09	1.81E-10	2.58E-09	2.20E-08
15	4.86E-09	3.05E-10	3.21E-09	3.22E-08
16	7.17E-09	4.73E-10	4.04E-09	4.39E-08
17	8.88E-09	2.62E-10	2.98E-09	2.76E-08
18	3.40E-09	1.91E-10	2.63E-09	2.28E-08
19	7.07E-09	2.53E-10	2.94E-09	2.71E-08
20	7.57E-09	2.62E-10	2.98E-09	2.77E-08
21	8.12E-09	2.72E-10	3.03E-09	2.85E-08
22	6.24E-09	2.41E-10	2.88E-09	2.62E-08
23	3.42E-09	1.93E-10	2.64E-09	2.30E-08

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
24	3.16E-09	1.87E-10	2.61E-09	2.24E-08
25	3.23E-09	1.89E-10	2.62E-09	2.26E-08
26	3.30E-09	1.91E-10	2.63E-09	2.27E-08
27	4.09E-09	2.07E-10	2.71E-09	2.39E-08
28	6.46E-09	2.50E-10	2.93E-09	2.69E-08
29	6.46E-09	2.50E-10	2.93E-09	2.69E-08
30	7.36E-09	2.69E-10	3.02E-09	2.83E-08
31	7.37E-09	2.69E-10	3.02E-09	2.83E-08
32	7.37E-09	2.69E-10	3.02E-09	2.83E-08
33	7.37E-09	2.69E-10	3.02E-09	2.83E-08
34	2.92E-09	1.85E-10	2.60E-09	2.22E-08
35	4.60E-09	2.49E-10	2.92E-09	2.69E-08
36	4.17E-09	2.47E-10	2.91E-09	2.68E-08
37	4.35E-09	2.56E-10	2.95E-09	2.74E-08
38	7.47E-09	4.53E-10	3.95E-09	4.27E-08
39	1.51E-08	7.52E-10	5.29E-09	8.61E-08
40	6.00E-09	4.21E-10	3.79E-09	4.03E-08
41	7.76E-09	2.65E-10	3.00E-09	2.82E-08
42	8.32E-09	2.75E-10	3.05E-09	2.90E-08
43	1.30E-08	3.33E-10	3.34E-09	3.27E-08
44	9.40E-09	2.90E-10	3.12E-09	2.96E-08
45	3.69E-09	1.98E-10	2.67E-09	2.35E-08
46	7.35E-09	2.67E-10	3.01E-09	2.84E-08
47	8.45E-09	2.89E-10	3.12E-09	3.01E-08
48	8.45E-09	2.89E-10	3.12E-09	3.01E-08
49	1.18E-08	3.32E-10	3.33E-09	3.27E-08
50	1.28E-08	3.50E-10	3.42E-09	3.41E-08
51	1.40E-08	3.70E-10	3.52E-09	3.55E-08
52	9.81E-09	3.06E-10	3.20E-09	3.09E-08
53	4.64E-09	2.64E-10	3.01E-09	2.99E-08
54	4.33E-09	2.59E-10	2.98E-09	2.94E-08
55	5.24E-09	2.81E-10	3.08E-09	2.95E-08
56	6.74E-09	3.32E-10	3.33E-09	3.28E-08

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
57	4.21E-09	2.56E-10	2.97E-09	2.91E-08
58	4.40E-09	2.66E-10	3.02E-09	3.00E-08
59	4.61E-09	2.76E-10	3.08E-09	3.10E-08
60	1.13E-08	5.47E-10	4.43E-09	5.06E-08
61	1.23E-08	5.88E-10	4.63E-09	5.38E-08
62	1.22E-08	5.88E-10	4.63E-09	5.38E-08
63	6.55E-09	3.31E-10	3.33E-09	3.28E-08
64	6.99E-09	3.48E-10	3.41E-09	3.41E-08
65	6.54E-09	3.61E-10	3.51E-09	3.76E-08
66	3.58E-09	2.34E-10	2.86E-09	2.70E-08
67	1.00E-08	5.44E-10	4.41E-09	5.03E-08
68	1.17E-08	6.29E-10	4.84E-09	5.70E-08
69	9.54E-09	5.24E-10	4.31E-09	4.87E-08
70	9.16E-09	5.17E-10	4.28E-09	4.82E-08
71	1.46E-08	7.60E-10	5.48E-09	6.48E-08
72	2.76E-08	1.69E-09	9.99E-09	1.24E-07
73	2.43E-08	1.74E-09	1.01E-08	1.50E-07
74	4.39E-09	4.30E-10	3.82E-09	4.01E-08
75	1.21E-08	3.59E-10	3.47E-09	3.51E-08
76	2.94E-08	5.77E-10	4.49E-09	7.85E-08
77	4.57E-09	2.23E-10	2.80E-09	2.56E-08
78	1.13E-08	3.61E-10	3.48E-09	3.53E-08
79	9.64E-09	3.25E-10	3.30E-09	3.26E-08
80	1.04E-08	3.42E-10	3.38E-09	3.38E-08
81	1.13E-08	3.61E-10	3.48E-09	3.52E-08
82	2.69E-08	5.83E-10	4.53E-09	7.91E-08
83	3.25E-08	6.78E-10	4.98E-09	8.48E-08
84	2.64E-08	5.85E-10	4.53E-09	7.92E-08
85	2.64E-08	5.85E-10	4.53E-09	7.92E-08
86	1.88E-08	6.10E-10	4.66E-09	8.11E-08
87	7.11E-09	3.55E-10	3.48E-09	3.74E-08
88	7.58E-09	3.74E-10	3.58E-09	3.92E-08
89	5.67E-09	2.86E-10	3.11E-09	3.01E-08

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
90	1.81E-08	6.13E-10	4.67E-09	8.13E-08
91	1.64E-08	6.95E-10	5.16E-09	6.08E-08
92	1.14E-08	5.53E-10	4.47E-09	5.17E-08
93	6.63E-09	3.33E-10	3.34E-09	3.32E-08
94	1.65E-08	7.41E-10	5.39E-09	6.43E-08
95	1.80E-08	8.02E-10	5.70E-09	6.89E-08
96	1.80E-08	8.03E-10	5.70E-09	6.90E-08
97	1.57E-08	6.14E-10	4.68E-09	8.14E-08
98	1.55E-08	7.31E-10	5.34E-09	6.35E-08
99	1.49E-08	6.13E-10	4.67E-09	8.14E-08
100	1.66E-08	7.86E-10	5.62E-09	6.77E-08
101	1.48E-08	7.22E-10	5.30E-09	6.29E-08
102	3.77E-09	2.42E-10	2.90E-09	2.79E-08
103	4.01E-09	2.56E-10	2.97E-09	2.93E-08
104	5.77E-09	3.42E-10	3.41E-09	3.63E-08
105	6.38E-09	3.75E-10	3.58E-09	3.92E-08
106	1.09E-08	5.73E-10	4.57E-09	5.33E-08
107	1.18E-08	6.15E-10	4.78E-09	5.67E-08
108	1.45E-08	7.17E-10	5.27E-09	6.25E-08
109	1.57E-08	7.75E-10	5.56E-09	6.68E-08
110	1.83E-08	8.92E-10	6.15E-09	7.58E-08
111	1.54E-08	6.59E-10	4.90E-09	8.43E-08
112	3.80E-09	2.44E-10	2.91E-09	2.82E-08
113	1.09E-08	5.73E-10	4.57E-09	5.33E-08
114	1.27E-08	6.61E-10	5.01E-09	6.04E-08
115	1.28E-08	6.67E-10	5.04E-09	6.09E-08
116	1.38E-08	7.19E-10	5.31E-09	6.51E-08
117	1.65E-08	8.47E-10	5.96E-09	7.54E-08
118	1.41E-08	7.11E-10	5.24E-09	6.20E-08
119	1.39E-08	6.11E-10	4.66E-09	8.13E-08
120	1.65E-08	7.12E-10	5.15E-09	8.76E-08
121	1.08E-08	5.72E-10	4.56E-09	5.32E-08
122	1.40E-08	7.10E-10	5.24E-09	6.19E-08

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
123	1.52E-08	7.68E-10	5.53E-09	6.63E-08
124	1.02E-08	5.83E-10	4.62E-09	5.41E-08
125	1.49E-08	8.02E-10	5.7E-09	6.89E-08
126	1.51E-08	6.99E-10	5.09E-09	8.68E-08
127	1.26E-08	6.04E-10	4.63E-09	8.09E-08
128	8.39E-09	5.00E-10	4.20E-09	4.75E-08
129	9.74E-09	5.76E-10	4.58E-09	5.35E-08
130	4.06E-08	1.86E-09	1.07E-08	1.60E-07
131	4.68E-08	1.44E-09	8.53E-09	1.22E-07
132	2.33E-08	1.21E-09	7.69E-09	9.52E-08
133	1.17E-08	6.71E-10	5.04E-09	5.90E-08
134	3.90E-08	1.85E-09	1.07E-08	1.59E-07
135	9.34E-09	6.15E-10	4.76E-09	5.47E-08
136	3.59E-09	2.57E-10	2.97E-09	2.86E-08
137	3.30E-08	1.88E-09	1.08E-08	1.61E-07
138	3.96E-08	2.24E-09	1.26E-08	1.84E-07
139	2.99E-08	1.74E-09	1.02E-08	1.52E-07
140	3.50E-08	2.17E-09	1.23E-08	1.8E-07
141	2.65E-08	1.68E-09	9.88E-09	1.49E-07
142	2.56E-09	1.76E-10	2.55E-09	2.15E-08
143	2.70E-09	1.93E-10	2.64E-09	2.31E-08
144	3.08E-09	2.35E-10	2.86E-09	2.66E-08
145	2.07E-08	1.65E-09	9.71E-09	1.46E-07
146	2.54E-09	1.75E-10	2.55E-09	2.13E-08
147	3.4E-09	3.02E-10	3.19E-09	3.14E-08
148	3.85E-09	3.69E-10	3.53E-09	3.68E-08
149	4.16E-09	4.01E-10	3.68E-09	3.83E-08
150	4.47E-09	4.46E-10	3.91E-09	4.17E-08
151	1.54E-08	4.58E-10	3.96E-09	4.18E-08
152	2.21E-08	1.13E-09	7.31E-09	9.08E-08
153	2.16E-08	1.12E-09	7.27E-09	9.03E-08
154	4.68E-08	2.23E-09	1.26E-08	1.85E-07
155	1.87E-08	1.07E-09	7.01E-09	8.64E-08

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
156	3.14E-08	2.14E-09	1.21E-08	1.80E-07
157	1.70E-08	1.59E-09	9.46E-09	1.44E-07
158	9.22E-09	3.13E-10	3.24E-09	3.20E-08
159	4.85E-09	2.49E-10	2.94E-09	2.89E-08
160	7.80E-09	3.12E-10	3.24E-09	3.20E-08
161	8.36E-09	3.28E-10	3.32E-09	3.32E-08
162	8.99E-09	3.45E-10	3.40E-09	3.45E-08
163	1.47E-08	4.61E-10	3.96E-09	4.08E-08
164	2.09E-08	5.75E-10	4.50E-09	7.96E-08
165	2.29E-08	6.19E-10	4.71E-09	8.24E-08
166	2.51E-08	6.67E-10	4.95E-09	8.54E-08
167	8.25E-09	3.27E-10	3.32E-09	3.32E-08
168	8.87E-09	3.45E-10	3.40E-09	3.45E-08
169	2.06E-08	5.76E-10	4.50E-09	7.96E-08
170	2.26E-08	6.20E-10	4.72E-09	8.24E-08
171	2.47E-08	6.68E-10	4.95E-09	8.56E-08
172	2.06E-08	5.76E-10	4.50E-09	7.96E-08
173	1.48E-08	5.80E-10	4.52E-09	8.01E-08
174	3.31E-08	1.37E-09	8.46E-09	1.04E-07
175	3.03E-08	1.32E-09	8.22E-09	1.00E-07
176	3.33E-08	1.45E-09	8.85E-09	1.09E-07
177	4.14E-08	1.73E-09	1.01E-08	1.54E-07
178	2.84E-08	9.18E-10	6.13E-09	9.84E-08
179	2.67E-08	1.22E-09	7.71E-09	9.33E-08
180	1.29E-08	7.05E-10	5.23E-09	6.29E-08
181	3.81E-08	1.70E-09	1.00E-08	1.52E-07
182	4.63E-08	2.05E-09	1.17E-08	1.75E-07
183	1.05E-08	5.94E-10	4.66E-09	5.41E-08
184	1.23E-08	6.92E-10	5.16E-09	6.19E-08
185	2.90E-08	1.40E-09	8.60E-09	1.06E-07
186	2.60E-08	1.29E-09	8.06E-09	9.83E-08
187	4.02E-08	1.85E-09	1.07E-08	1.62E-07
188	4.43E-08	2.04E-09	1.16E-08	1.74E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
189	3.09E-08	1.52E-09	9.19E-09	1.14E-07
190	2.56E-08	1.27E-09	7.95E-09	9.67E-08
191	3.93E-08	1.80E-09	1.05E-08	1.59E-07
192	1.09E-08	6.31E-10	4.85E-09	5.71E-08
193	3.40E-08	1.66E-09	9.81E-09	1.50E-07
194	3.74E-08	1.82E-09	1.06E-08	1.60E-07
195	2.74E-08	1.46E-09	8.89E-09	1.10E-07
196	3.12E-08	1.63E-09	9.63E-09	1.48E-07
197	2.17E-08	1.21E-09	7.65E-09	9.25E-08
198	2.61E-08	1.44E-09	8.82E-09	1.09E-07
199	4.06E-08	2.10E-09	1.19E-08	1.78E-07
200	3.04E-08	1.61E-09	9.58E-09	1.47E-07
201	3.67E-08	1.95E-09	1.12E-08	1.68E-07
202	3.67E-08	1.94E-09	1.12E-08	1.68E-07
203	3.08E-08	1.29E-09	7.75E-09	1.10E-07
204	3.97E-08	2.08E-09	1.19E-08	1.77E-07
205	2.06E-08	1.19E-09	7.55E-09	9.12E-08
206	3.20E-08	1.72E-09	1.01E-08	1.53E-07
207	2.90E-08	1.59E-09	9.48E-09	1.45E-07
208	3.18E-08	1.75E-09	1.02E-08	1.56E-07
209	1.06E-07	4.53E-09	2.28E-08	2.72E-07
210	1.32E-07	5.89E-09	2.87E-08	3.16E-07
211	2.35E-08	1.49E-09	8.98E-09	1.39E-07
212	2.34E-08	1.49E-09	8.98E-09	1.39E-07
213	6.13E-08	2.94E-09	1.59E-08	2.20E-07
214	2.18E-08	1.46E-09	8.80E-09	1.37E-07
215	5.97E-08	3.35E-09	1.76E-08	2.29E-07
216	5.43E-08	2.88E-09	1.56E-08	2.20E-07
217	8.91E-08	4.25E-09	2.19E-08	2.79E-07
218	1.92E-08	1.39E-09	8.47E-09	1.32E-07
219	2.09E-08	1.52E-09	9.11E-09	1.41E-07
220	7.89E-08	3.96E-09	2.05E-08	2.63E-07
221	1.68E-08	1.32E-09	8.12E-09	1.28E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
222	1.53E-08	1.27E-09	7.89E-09	1.24E-07
223	3.03E-08	2.18E-09	1.23E-08	1.84E-07
224	1.37E-07	6.95E-09	3.36E-08	3.66E-07
225	1.68E-07	8.50E-09	4.08E-08	4.38E-07
226	4.70E-09	4.19E-10	3.78E-09	4.03E-08
227	1.34E-08	1.20E-09	7.53E-09	1.20E-07
228	7.78E-09	7.69E-10	5.48E-09	6.21E-08
229	3.49E-09	3.16E-10	3.26E-09	3.22E-08
230	3.53E-09	3.35E-10	3.35E-09	3.37E-08
231	3.86E-09	2.28E-10	2.83E-09	2.69E-08
232	3.81E-08	1.59E-09	9.56E-09	1.20E-07
233	2.77E-08	1.42E-09	8.70E-09	1.08E-07
234	6.95E-08	3.32E-09	1.75E-08	2.29E-07
235	5.23E-08	2.32E-09	1.30E-08	1.94E-07
236	2.80E-08	1.60E-09	9.50E-09	1.47E-07
237	2.55E-08	1.48E-09	8.93E-09	1.39E-07
238	2.63E-08	1.54E-09	9.25E-09	1.43E-07
239	9.96E-08	3.93E-09	2.04E-08	2.63E-07
240	6.21E-08	3.04E-09	1.64E-08	2.28E-07
241	4.19E-09	3.19E-10	3.28E-09	3.34E-08
242	7.90E-08	3.84E-09	2.00E-08	2.59E-07
243	9.56E-08	4.63E-09	2.37E-08	3.02E-07
244	1.60E-07	6.46E-09	3.14E-08	3.46E-07
245	2.98E-08	1.84E-09	1.07E-08	1.63E-07
246	1.82E-08	1.37E-09	8.40E-09	1.32E-07
247	6.85E-08	3.61E-09	1.90E-08	2.52E-07
248	7.43E-09	6.94E-10	5.12E-09	5.74E-08
249	6.41E-08	4.31E-09	2.22E-08	2.85E-07
250	8.14E-08	5.02E-09	2.52E-08	3.01E-07
251	4.77E-08	1.11E-09	7.00E-09	1.06E-07
252	7.25E-08	3.23E-09	1.71E-08	2.26E-07
253	7.73E-08	3.86E-09	2.01E-08	2.61E-07
254	7.58E-08	3.85E-09	2.00E-08	2.61E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
255	5.13E-08	2.74E-09	1.48E-08	2.04E-07
256	1.63E-07	7.31E-09	3.54E-08	3.90E-07
257	4.27E-08	5.89E-09	2.89E-08	3.22E-07
258	5.58E-08	1.14E-09	7.07E-09	1.03E-07
259	3.32E-08	8.93E-10	5.97E-09	9.45E-08
260	6.79E-08	1.22E-09	7.43E-09	1.07E-07
261	5.22E-08	1.16E-09	7.16E-09	1.04E-07
262	5.76E-08	1.27E-09	7.67E-09	1.10E-07
263	5.14E-08	1.17E-09	7.18E-09	1.05E-07
264	6.27E-08	1.39E-09	8.25E-09	1.16E-07
265	5.14E-08	1.17E-09	7.18E-09	1.04E-07
266	5.70E-08	1.35E-09	8.07E-09	1.14E-07
267	3.67E-08	1.23E-09	7.51E-09	1.09E-07
268	9.69E-08	3.70E-09	1.94E-08	2.54E-07
269	9.12E-08	3.68E-09	1.93E-08	2.53E-07
270	4.04E-08	1.49E-09	8.70E-09	1.22E-07
271	1.18E-07	4.36E-09	2.22E-08	2.70E-07
272	5.94E-08	2.63E-09	1.43E-08	1.98E-07
273	1.08E-07	4.20E-09	2.14E-08	2.62E-07
274	5.37E-09	3.49E-10	3.44E-09	3.64E-08
275	5.57E-08	2.53E-09	1.39E-08	1.95E-07
276	1.12E-07	4.36E-09	2.22E-08	2.71E-07
277	3.17E-08	1.67E-09	9.90E-09	1.54E-07
278	1.10E-07	4.36E-09	2.22E-08	2.71E-07
279	1.25E-07	5.12E-09	2.57E-08	3.10E-07
280	6.48E-09	4.28E-10	3.85E-09	4.33E-08
281	4.49E-08	2.18E-09	1.23E-08	1.78E-07
282	1.08E-07	4.36E-09	2.22E-08	2.71E-07
283	5.04E-09	3.37E-10	3.38E-09	3.54E-08
284	6.99E-08	3.26E-09	1.73E-08	2.30E-07
285	1.06E-07	4.36E-09	2.22E-08	2.71E-07
286	1.17E-07	4.82E-09	2.43E-08	2.94E-07
287	1.09E-07	4.63E-09	2.34E-08	2.85E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
288	1.20E-07	5.11E-09	2.57E-08	3.10E-07
289	1.25E-07	5.32E-09	2.67E-08	3.20E-07
290	4.27E-08	2.16E-09	1.22E-08	1.77E-07
291	1.04E-07	4.36E-09	2.22E-08	2.71E-07
292	1.47E-07	5.65E-09	2.78E-08	3.13E-07
293	1.38E-07	5.50E-09	2.71E-08	3.05E-07
294	2.66E-08	1.46E-09	8.86E-09	1.40E-07
295	1.01E-07	4.36E-09	2.22E-08	2.71E-07
296	9.36E-08	4.18E-09	2.14E-08	2.62E-07
297	2.56E-08	1.44E-09	8.76E-09	1.39E-07
298	2.32E-08	1.33E-09	8.24E-09	1.32E-07
299	9.97E-08	4.35E-09	2.21E-08	2.70E-07
300	1.15E-07	5.25E-09	2.64E-08	3.17E-07
301	4.40E-08	2.49E-09	1.38E-08	1.98E-07
302	7.07E-08	3.69E-09	1.93E-08	2.54E-07
303	5.34E-08	2.87E-09	1.54E-08	2.07E-07
304	6.51E-08	3.49E-09	1.83E-08	2.42E-07
305	8.92E-08	4.33E-09	2.20E-08	2.69E-07
306	1.09E-07	5.28E-09	2.65E-08	3.18E-07
307	1.59E-07	6.97E-09	3.39E-08	3.75E-07
308	1.29E-07	5.71E-09	2.81E-08	3.16E-07
309	4.20E-09	3.04E-10	3.21E-09	3.25E-08
310	2.15E-08	1.35E-09	8.34E-09	1.33E-07
311	6.33E-08	2.95E-09	1.59E-08	2.21E-07
312	4.15E-08	2.36E-09	1.31E-08	1.86E-07
313	7.04E-08	3.22E-09	1.71E-08	2.33E-07
314	4.66E-08	2.61E-09	1.42E-08	1.97E-07
315	5.11E-08	2.84E-09	1.53E-08	2.06E-07
316	8.74E-08	4.32E-09	2.20E-08	2.69E-07
317	1.96E-07	8.15E-09	3.85E-08	3.89E-07
318	7.84E-08	4.12E-09	2.10E-08	2.58E-07
319	7.35E-08	4.23E-09	2.16E-08	2.64E-07
320	7.32E-08	4.23E-09	2.16E-08	2.64E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
321	5.83E-08	2.17E-09	1.15E-08	1.38E-07
322	6.65E-08	4.02E-09	2.06E-08	2.53E-07
323	6.96E-08	4.20E-09	2.14E-08	2.63E-07
324	3.53E-09	2.71E-10	3.04E-09	2.96E-08
325	6.90E-08	4.19E-09	2.14E-08	2.62E-07
326	1.50E-07	6.47E-09	3.16E-08	3.53E-07
327	2.05E-07	8.18E-09	3.85E-08	3.86E-07
328	6.45E-08	4.14E-09	2.12E-08	2.60E-07
329	3.33E-09	2.59E-10	2.98E-09	2.85E-08
330	6.22E-08	4.12E-09	2.10E-08	2.58E-07
331	7.59E-08	5.02E-09	2.53E-08	3.05E-07
332	1.38E-07	6.50E-09	3.18E-08	3.55E-07
333	1.53E-07	7.20E-09	3.50E-08	3.88E-07
334	1.15E-07	6.93E-09	3.37E-08	3.74E-07
335	9.74E-08	6.05E-09	2.96E-08	3.32E-07
336	1.96E-07	8.18E-09	3.87E-08	3.92E-07
337	1.50E-08	1.23E-09	7.73E-09	1.24E-07
338	2.51E-08	1.93E-09	1.10E-08	1.60E-07
339	6.20E-08	4.11E-09	2.10E-08	2.58E-07
340	1.53E-07	7.59E-09	3.68E-08	4.06E-07
341	7.00E-08	2.74E-09	1.39E-08	1.54E-07
342	5.19E-08	3.96E-09	2.03E-08	2.50E-07
343	1.44E-07	7.97E-09	3.85E-08	4.25E-07
344	1.28E-07	7.20E-09	3.50E-08	3.88E-07
345	8.77E-09	8.63E-10	5.93E-09	9.98E-08
346	1.58E-08	1.52E-09	9.05E-09	1.37E-07
347	3.35E-08	2.61E-09	1.43E-08	2.01E-07
348	1.92E-08	1.81E-09	1.05E-08	1.52E-07
349	4.66E-08	3.38E-09	1.78E-08	2.37E-07
350	2.98E-08	2.76E-09	1.49E-08	2.01E-07
351	2.48E-08	2.28E-09	1.26E-08	1.73E-07
352	9.01E-08	5.98E-09	2.98E-08	3.56E-07
353	7.37E-08	4.9E-09	2.47E-08	3E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
354	6.68E-08	4.58E-09	2.32E-08	2.83E-07
355	5.03E-08	4.23E-09	2.16E-08	2.64E-07
356	1.31E-07	7.94E-09	3.84E-08	4.23E-07
357	1.07E-07	6.49E-09	3.17E-08	3.55E-07
358	1.08E-07	6.50E-09	3.17E-08	3.55E-07
359	1.19E-07	7.18E-09	3.49E-08	3.87E-07
360	1.32E-07	7.94E-09	3.84E-08	4.23E-07
361	7.13E-08	5.50E-09	2.71E-08	3.06E-07
362	6.71E-08	5.28E-09	2.61E-08	2.96E-07
363	1.89E-07	9.47E-09	4.40E-08	4.23E-07
364	2.99E-08	2.76E-09	1.49E-08	2.01E-07
365	1.31E-07	7.94E-09	3.84E-08	4.23E-07
366	2.78E-08	2.80E-09	1.51E-08	2.03E-07
367	3.93E-08	3.69E-09	1.90E-08	2.36E-07
368	4.31E-08	4.06E-09	2.08E-08	2.55E-07
369	3.65E-08	3.48E-09	1.80E-08	2.25E-07
370	4.02E-08	3.83E-09	1.97E-08	2.43E-07
371	6.85E-09	7.80E-10	5.52E-09	9.42E-08
372	5.41E-08	5.23E-09	2.59E-08	2.93E-07
373	2.38E-08	2.29E-09	1.27E-08	1.81E-07
374	7.52E-08	6.01E-09	2.95E-08	3.32E-07
375	8.30E-08	6.92E-09	3.37E-08	3.75E-07
376	1.07E-07	8.91E-09	4.29E-08	4.69E-07
377	8.09E-08	6.89E-09	3.36E-08	3.74E-07
378	4.14E-08	4.92E-09	2.44E-08	2.78E-07
379	2.77E-08	4.38E-09	2.19E-08	2.52E-07
380	3.93E-08	5.44E-09	2.69E-08	3.04E-07
381	2.82E-08	5.06E-09	2.50E-08	2.83E-07
382	6.69E-08	1.36E-09	8.03E-09	1.01E-07
383	6.29E-08	1.38E-09	8.16E-09	1.03E-07
384	7.06E-08	1.63E-09	9.32E-09	1.15E-07
385	6.20E-08	1.39E-09	8.18E-09	1.03E-07
386	6.85E-08	1.52E-09	8.79E-09	1.09E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
387	9.51E-09	4.27E-10	3.89E-09	3.61E-08
388	1.59E-07	5.83E-09	2.87E-08	3.17E-07
389	5.14E-09	3.26E-10	3.37E-09	2.70E-08
390	5.41E-09	3.44E-10	3.46E-09	2.86E-08
391	1.39E-07	5.47E-09	2.71E-08	3.00E-07
392	1.30E-07	5.31E-09	2.63E-08	2.92E-07
393	7.30E-08	3.52E-09	1.86E-08	2.40E-07
394	1.13E-07	5.05E-09	2.56E-08	3.03E-07
395	1.34E-07	5.48E-09	2.71E-08	3.01E-07
396	1.48E-07	6.05E-09	2.98E-08	3.28E-07
397	5.70E-08	2.87E-09	1.55E-08	2.02E-07
398	1.31E-07	5.49E-09	2.72E-08	3.01E-07
399	1.29E-07	5.49E-09	2.72E-08	3.01E-07
400	1.40E-07	6.71E-09	3.28E-08	3.60E-07
401	7.00E-08	3.36E-09	1.78E-08	2.31E-07
402	1.22E-07	6.27E-09	3.08E-08	3.40E-07
403	4.91E-08	3.58E-09	1.86E-08	2.25E-07
404	5.42E-08	3.95E-09	2.04E-08	2.45E-07
405	1.35E-07	6.93E-09	3.39E-08	3.72E-07
406	9.40E-08	6.18E-09	3.04E-08	3.36E-07
407	1.04E-07	6.83E-09	3.34E-08	3.67E-07
408	7.52E-08	6.28E-09	3.08E-08	3.39E-07
409	6.17E-08	5.13E-09	2.55E-08	2.84E-07
410	2.61E-08	2.56E-09	1.40E-08	1.82E-07
411	7.68E-08	5.52E-09	2.78E-08	3.28E-07
412	1.15E-07	7.55E-09	3.68E-08	4.02E-07
413	1.56E-07	1.03E-08	4.92E-08	5.32E-07
414	8.64E-08	5.88E-09	2.90E-08	3.21E-07
415	6.17E-08	5.14E-09	2.55E-08	2.84E-07
416	6.17E-08	5.13E-09	2.55E-08	2.84E-07
417	6.81E-08	5.67E-09	2.80E-08	3.10E-07
418	7.53E-08	6.28E-09	3.08E-08	3.39E-07
419	7.08E-08	6.00E-09	2.95E-08	3.26E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
420	5.44E-08	5.01E-09	2.49E-08	2.78E-07
421	3.61E-08	3.65E-09	1.89E-08	2.28E-07
422	4.55E-08	4.80E-09	2.40E-08	2.68E-07
423	1.02E-07	8.34E-09	3.96E-08	3.97E-07
424	7.23E-08	1.40E-09	8.25E-09	2.55E-07
425	6.84E-08	1.43E-09	8.39E-09	2.57E-07
426	5.45E-08	1.38E-09	8.15E-09	2.54E-07
427	7.20E-08	1.69E-09	9.42E-09	2.61E-07
428	3.25E-08	8.96E-10	6.04E-09	2.40E-07
429	6.76E-08	1.44E-09	8.42E-09	2.57E-07
430	6.56E-08	1.66E-09	9.46E-09	2.68E-07
431	1.20E-08	4.95E-10	4.21E-09	1.93E-07
432	6.60E-08	1.45E-09	8.47E-09	2.58E-07
433	1.94E-07	5.54E-09	2.75E-08	4.60E-07
434	1.94E-07	5.55E-09	2.75E-08	4.60E-07
435	1.89E-07	5.57E-09	2.76E-08	4.61E-07
436	1.60E-07	6.17E-09	3.04E-08	4.90E-07
437	1.62E-07	6.37E-09	3.13E-08	5.00E-07
438	1.52E-07	6.17E-09	3.04E-08	4.90E-07
439	1.67E-07	5.67E-09	2.81E-08	4.67E-07
440	1.65E-07	5.68E-09	2.81E-08	4.67E-07
441	1.57E-07	5.70E-09	2.83E-08	4.68E-07
442	1.92E-07	6.97E-09	3.42E-08	5.31E-07
443	1.36E-07	6.17E-09	3.04E-08	4.90E-07
444	1.55E-07	5.71E-09	2.83E-08	4.69E-07
445	1.32E-07	5.39E-09	2.72E-08	4.78E-07
446	1.52E-07	5.71E-09	2.83E-08	4.69E-07
447	7.46E-08	3.80E-09	1.97E-08	3.91E-07
448	1.49E-07	5.72E-09	2.83E-08	4.69E-07
449	1.12E-07	5.21E-09	2.60E-08	4.43E-07
450	1.34E-07	6.37E-09	3.13E-08	5.00E-07
451	1.13E-07	4.64E-09	2.37E-08	4.38E-07
452	1.44E-07	5.73E-09	2.84E-08	4.70E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
453	1.32E-07	6.36E-09	3.13E-08	5.00E-07
454	5.22E-08	2.64E-09	1.45E-08	3.48E-07
455	1.03E-07	5.19E-09	2.59E-08	4.43E-07
456	1.55E-07	6.15E-09	3.03E-08	4.87E-07
457	1.13E-07	5.30E-09	2.68E-08	4.73E-07
458	1.63E-07	7.01E-09	3.44E-08	5.33E-07
459	1.30E-07	5.74E-09	2.84E-08	4.70E-07
460	4.69E-08	2.56E-09	1.41E-08	3.43E-07
461	5.74E-08	3.49E-09	1.82E-08	3.74E-07
462	1.29E-07	5.74E-09	2.85E-08	4.71E-07
463	9.50E-08	5.16E-09	2.57E-08	4.41E-07
464	1.49E-07	7.32E-09	3.49E-08	5.03E-07
465	3.78E-08	2.39E-09	1.33E-08	3.32E-07
466	1.10E-07	5.71E-09	2.83E-08	4.69E-07
467	1.38E-07	7.19E-09	3.52E-08	5.43E-07
468	1.05E-07	5.68E-09	2.82E-08	4.68E-07
469	1.04E-07	5.68E-09	2.81E-08	4.67E-07
470	9.79E-08	5.65E-09	2.80E-08	4.66E-07
471	2.74E-07	1.09E-08	4.89E-08	8.49E-07
472	9.50E-08	5.63E-09	2.79E-08	4.65E-07
473	1.58E-07	9.30E-09	4.50E-08	6.47E-07
474	1.53E-07	8.02E-09	3.81E-08	5.34E-07
475	2.25E-07	9.95E-09	4.58E-08	8.46E-07
476	1.68E-07	9.78E-09	4.50E-08	8.39E-07
477	2.06E-07	1.20E-08	5.48E-08	9.23E-07
478	4.56E-08	3.19E-09	1.71E-08	3.75E-07
479	6.89E-08	4.45E-09	2.28E-08	4.27E-07
480	3.93E-08	3.15E-09	1.66E-08	3.56E-07
481	9.44E-08	5.63E-09	2.79E-08	4.65E-07
482	1.15E-07	6.81E-09	3.34E-08	5.23E-07
483	7.50E-08	5.45E-09	2.71E-08	4.55E-07
484	1.13E-07	7.39E-09	3.52E-08	5.06E-07
485	2.18E-07	1.02E-08	4.74E-08	6.00E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
486	8.55E-08	5.55E-09	2.76E-08	4.61E-07
487	2.04E-07	1.02E-08	4.69E-08	8.57E-07
488	8.06E-08	5.50E-09	2.73E-08	4.59E-07
489	7.66E-08	5.46E-09	2.71E-08	4.56E-07
490	9.59E-08	6.98E-09	3.42E-08	5.32E-07
491	7.85E-08	5.71E-09	2.83E-08	4.69E-07
492	8.68E-08	6.31E-09	3.11E-08	4.99E-07
493	9.58E-08	6.97E-09	3.42E-08	5.32E-07
494	7.20E-08	5.40E-09	2.68E-08	4.53E-07
495	5.05E-08	4.64E-09	2.33E-08	4.15E-07
496	5.57E-08	5.12E-09	2.55E-08	4.38E-07
497	1.45E-07	9.21E-09	4.35E-08	5.86E-07
498	1.22E-07	8.10E-09	3.85E-08	5.38E-07
499	1.85E-07	1.05E-08	4.80E-08	8.66E-07
500	2.05E-07	1.16E-08	5.29E-08	9.09E-07
501	6.14E-08	5.66E-09	2.80E-08	4.65E-07
502	5.76E-08	5.38E-09	2.67E-08	4.51E-07
503	2.27E-07	1.28E-08	5.84E-08	9.56E-07
504	6.36E-08	5.26E-09	2.62E-08	4.47E-07
505	4.43E-08	4.49E-09	2.26E-08	4.07E-07
506	1.70E-07	1.06E-08	4.87E-08	8.72E-07
507	4.81E-08	4.93E-09	2.46E-08	4.29E-07
508	1.15E-07	9.15E-09	4.28E-08	5.65E-07
509	1.50E-07	1.08E-08	4.96E-08	8.80E-07
510	5.38E-08	5.46E-09	2.71E-08	4.55E-07
511	4.78E-08	4.91E-09	2.46E-08	4.29E-07
512	5.18E-08	5.24E-09	2.61E-08	4.45E-07
513	1.64E-07	4.07E-09	2.11E-08	4.14E-07
514	5.86E-08	1.42E-09	8.36E-09	2.58E-07
515	7.98E-08	1.71E-09	9.53E-09	2.64E-07
516	1.06E-07	2.27E-09	1.17E-08	5.46E-07
517	1.62E-07	4.08E-09	2.11E-08	4.14E-07
518	1.98E-07	4.97E-09	2.54E-08	4.64E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
519	1.95E-07	5.67E-09	2.82E-08	4.74E-07
520	7.90E-08	1.71E-09	9.56E-09	2.64E-07
521	8.20E-08	1.75E-09	9.70E-09	2.64E-07
522	1.19E-07	3.64E-09	1.90E-08	3.89E-07
523	7.89E-08	1.71E-09	9.57E-09	2.64E-07
524	6.57E-08	1.71E-09	9.53E-09	2.64E-07
525	9.27E-08	2.07E-09	1.09E-08	5.45E-07
526	2.34E-07	6.79E-09	3.28E-08	4.94E-07
527	2.29E-07	6.84E-09	3.30E-08	4.96E-07
528	1.32E-07	4.97E-09	2.54E-08	4.64E-07
529	2.17E-07	8.15E-09	3.90E-08	5.54E-07
530	1.01E-07	4.05E-09	2.1E-08	4.13E-07
531	1.13E-07	5.17E-09	2.59E-08	4.49E-07
532	2.21E-07	7.18E-09	3.45E-08	5.06E-07
533	2.71E-07	8.04E-09	3.79E-08	5.21E-07
534	2.02E-07	7.04E-09	3.40E-08	5.06E-07
535	9.29E-08	5.01E-09	2.55E-08	4.65E-07
536	8.60E-08	3.96E-09	2.06E-08	4.08E-07
537	9.51E-08	4.36E-09	2.25E-08	4.31E-07
538	1.06E-07	4.82E-09	2.47E-08	4.56E-07
539	9.61E-08	5.09E-09	2.55E-08	4.45E-07
540	2.08E-07	7.89E-09	3.79E-08	5.44E-07
541	1.72E-07	8.13E-09	3.89E-08	5.54E-07
542	2.63E-07	1.10E-08	5.05E-08	8.94E-07
543	8.39E-08	3.94E-09	2.05E-08	4.07E-07
544	1.84E-07	7.16E-09	3.45E-08	5.11E-07
545	2.03E-07	7.92E-09	3.80E-08	5.46E-07
546	1.09E-07	5.81E-09	2.89E-08	4.82E-07
547	1.79E-07	7.19E-09	3.46E-08	5.12E-07
548	9.69E-08	5.72E-09	2.85E-08	4.77E-07
549	8.42E-08	5.14E-09	2.58E-08	4.48E-07
550	7.14E-08	4.46E-09	2.26E-08	4.13E-07
551	1.61E-07	7.27E-09	3.50E-08	5.16E-07

Pipeline	Hydrogen Failure Rates (per m per year) for V3.1 PIPIN			
	Rupture	Large hole	Small hole	Pinhole
552	2.07E-07	9.88E-09	4.53E-08	8.38E-07
553	5.75E-08	3.62E-09	1.89E-08	3.88E-07
554	1.60E-07	9.77E-09	4.58E-08	6.00E-07
555	5.73E-08	3.61E-09	1.89E-08	3.88E-07
556	1.40E-07	7.33E-09	3.53E-08	5.19E-07
557	1.23E-07	7.35E-09	3.54E-08	5.20E-07
558	9.30E-08	6.76E-09	3.27E-08	4.92E-07
559	1.98E-07	9.91E-09	4.59E-08	8.56E-07
560	2.18E-07	1.05E-08	4.80E-08	8.62E-07
561	2.41E-07	1.16E-08	5.30E-08	9.05E-07
562	2.38E-07	1.11E-08	5.01E-08	8.67E-07
563	3.24E-07	1.50E-08	6.73E-08	1.01E-06
564	1.23E-07	7.35E-09	3.54E-08	5.20E-07
565	1.89E-07	1.00E-08	4.68E-08	6.05E-07
566	5.65E-08	4.73E-09	2.39E-08	4.27E-07
567	1.04E-07	7.54E-09	3.62E-08	5.29E-07
568	1.15E-07	8.33E-09	3.99E-08	5.65E-07
569	1.27E-07	9.22E-09	4.39E-08	6.05E-07
570	1.98E-07	1.26E-08	5.79E-08	9.62E-07
571	5.43E-08	4.89E-09	2.46E-08	4.36E-07
572	1.36E-08	2.74E-09	1.45E-08	3.23E-07
573	1.91E-07	4.83E-09	2.46E-08	7.48E-07
574	9.64E-08	1.99E-09	1.07E-08	8.46E-07
575	2.25E-07	5.48E-09	2.74E-08	7.65E-07
576	9.54E-08	2.00E-09	1.07E-08	8.47E-07
577	2.89E-07	8.22E-09	3.87E-08	1.10E-06
578	1.82E-07	7.09E-09	3.49E-08	8.48E-07
579	5.19E-08	3.19E-09	1.70E-08	6.75E-07
580	6.36E-08	5.92E-09	2.94E-08	7.86E-07
581	5.23E-08	4.85E-09	2.44E-08	7.32E-07
582	5.77E-08	5.36E-09	2.68E-08	7.57E-07
583	3.41E-08	4.34E-09	2.20E-08	7.04E-07
584	2.15E-07	1.10E-08	5.28E-08	1.03E-06

15.2 Comparison to methane failure rates

In the subsequent table, the differences are the hydrogen release rates – the methane release rates. The percentages are then calculated using the equation (hydrogen – methane)/methane.

Table 22 Comparison of hydrogen failure rates to methane failure rates

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
1	7.0E-11	1.0E-12	1.0E-11	1.0E-10	2.7	0.6	0.4	0.5
2	8.0E-10	7.0E-12	3.0E-11	6.0E-10	30.0	4.0	1.2	2.8
3	1.2E-09	7.0E-12	4.0E-11	7.0E-10	42.7	3.8	1.6	3.2
4	1.8E-09	8.0E-12	4.0E-11	7.0E-10	58.6	4.2	1.5	3.1
5	3.8E-10	4.0E-12	2.0E-11	4.0E-10	13.7	2.2	0.8	1.8
6	1.1E-09	1.0E-11	5.0E-11	9.0E-10	41.5	5.6	1.9	4.2
7	9.5E-10	6.0E-12	3.0E-11	5.0E-10	28.1	3.0	1.1	2.1
8	2.3E-09	4.4E-11	2.2E-10	3.3E-09	68.6	20.9	8.1	13.9
9	2.6E-10	1.5E-11	8.0E-11	1.5E-09	10.2	8.6	3.1	7.1
10	1.7E-09	8.0E-12	4.0E-11	8.0E-10	44.2	3.8	1.5	3.3
11	1.5E-09	1.3E-11	6.0E-11	1.1E-09	44.1	6.5	2.2	4.7
12	1.4E-09	1.6E-11	8.0E-11	1.4E-09	42.9	8.2	3.0	6.1
13	1.1E-09	1.3E-11	7.0E-11	1.2E-09	36.9	6.8	2.7	5.3
14	1.7E-10	9.0E-12	5.0E-11	1.0E-09	6.7	5.2	2.0	4.8
15	2.0E-09	1.0E-10	5.1E-10	8.5E-09	71.1	48.8	18.9	35.9
16	3.9E-09	2.1E-10	1.1E-09	1.6E-08	119.3	81.2	35.6	59.1
17	3.4E-09	1.7E-11	8.0E-11	1.3E-09	62.6	6.9	2.8	4.9
18	6.7E-10	1.2E-11	6.0E-11	1.2E-09	24.5	6.7	2.3	5.6
19	2.9E-09	3.0E-11	1.5E-10	2.4E-09	67.9	13.5	5.4	9.7
20	3.2E-09	3.3E-11	1.6E-10	2.6E-09	72.4	14.4	5.7	10.4
21	3.5E-09	3.7E-11	1.8E-10	2.9E-09	76.9	15.7	6.3	11.3
22	2.4E-09	2.6E-11	1.3E-10	2.1E-09	62.5	12.1	4.7	8.7
23	7.0E-10	1.4E-11	7.0E-11	1.4E-09	25.7	7.8	2.7	6.5
24	5.1E-10	1.1E-11	6.0E-11	1.0E-09	19.2	6.2	2.4	4.7
25	5.6E-10	1.2E-11	6.0E-11	1.2E-09	21.0	6.8	2.3	5.6
26	6.2E-10	1.3E-11	7.0E-11	1.2E-09	23.1	7.3	2.7	5.6
27	1.2E-09	2.0E-11	1.0E-10	1.7E-09	39.6	10.7	3.8	7.7

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
28	2.6E-09	3.4E-11	1.8E-10	2.7E-09	69.1	15.7	6.5	11.2
29	2.6E-09	3.4E-11	1.8E-10	2.7E-09	69.1	15.7	6.5	11.2
30	3.2E-09	4.3E-11	2.2E-10	3.3E-09	78.6	19.0	7.9	13.2
31	3.3E-09	4.3E-11	2.2E-10	3.3E-09	78.9	19.0	7.9	13.2
32	3.3E-09	4.3E-11	2.2E-10	3.3E-09	78.9	19.0	7.9	13.2
33	3.3E-09	4.3E-11	2.2E-10	3.3E-09	78.9	19.0	7.9	13.2
34	3.4E-10	1.1E-11	6.0E-11	1.0E-09	13.2	6.3	2.4	4.7
35	1.7E-09	5.1E-11	2.6E-10	4.0E-09	57.0	25.8	9.8	17.5
36	1.4E-09	5.2E-11	2.6E-10	4.1E-09	48.4	26.7	9.8	18.1
37	1.5E-09	5.9E-11	2.9E-10	4.5E-09	53.2	29.9	10.9	19.7
38	4.1E-09	2.0E-10	1.0E-09	1.5E-08	124.3	77.0	33.9	56.4
39	8.4E-09	2.7E-10	1.3E-09	1.6E-08	126.0	57.3	32.9	22.1
40	3.0E-09	1.8E-10	9.1E-10	1.4E-08	97.4	74.0	31.6	53.2
41	3.9E-09	5.2E-11	2.6E-10	4.1E-09	103.1	24.4	9.5	17.0
42	4.4E-09	5.7E-11	2.9E-10	4.5E-09	109.6	26.1	10.5	18.4
43	7.0E-09	7.0E-11	3.5E-10	5.3E-09	116.7	26.6	11.7	19.3
44	5.0E-09	5.9E-11	3.0E-10	4.4E-09	115.1	25.5	10.6	17.5
45	9.8E-10	2.0E-11	1.1E-10	1.9E-09	36.2	11.2	4.3	8.8
46	3.7E-09	5.6E-11	2.8E-10	4.5E-09	102.5	26.5	10.3	18.8
47	4.6E-09	6.9E-11	3.5E-10	5.5E-09	117.8	31.4	12.6	22.4
48	4.6E-09	6.9E-11	3.5E-10	5.5E-09	117.8	31.4	12.6	22.4
49	6.4E-09	7.7E-11	3.8E-10	5.8E-09	119.7	30.2	12.9	21.6
50	7.1E-09	8.6E-11	4.3E-10	6.6E-09	125.7	32.6	14.4	24.0
51	8.0E-09	9.6E-11	4.8E-10	7.2E-09	132.6	35.0	15.8	25.4
52	5.4E-09	7.1E-11	3.5E-10	5.4E-09	120.9	30.2	12.3	21.2
53	1.9E-09	7.4E-11	3.8E-10	7.2E-09	68.1	38.9	14.4	31.7
54	1.6E-09	7.1E-11	3.6E-10	6.8E-09	59.2	37.8	13.7	30.1
55	2.2E-09	7.6E-11	3.8E-10	6.0E-09	74.7	37.1	14.1	25.5
56	3.4E-09	1.1E-10	5.2E-10	7.8E-09	100.6	46.3	18.5	31.2
57	1.5E-09	6.8E-11	3.6E-10	6.6E-09	55.9	36.2	13.8	29.3
58	1.7E-09	7.6E-11	3.9E-10	7.3E-09	61.2	40.0	14.8	32.2
59	1.9E-09	8.4E-11	4.4E-10	8.1E-09	67.6	43.8	16.7	35.4
60	7.4E-09	2.6E-10	1.3E-09	2.1E-08	189.7	93.3	43.4	70.9

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
61	8.3E-09	2.9E-10	1.5E-09	2.3E-08	203.7	99.3	47.0	75.8
62	8.2E-09	2.9E-10	1.5E-09	2.3E-08	201.2	99.3	46.5	75.8
63	3.2E-09	1.1E-10	5.3E-10	7.9E-09	97.9	46.5	18.9	31.7
64	3.6E-09	1.2E-10	5.8E-10	8.7E-09	105.6	50.0	20.5	34.3
65	3.5E-09	1.4E-10	7.4E-10	1.3E-08	113.7	65.6	26.7	50.4
66	9.6E-10	5.1E-11	2.7E-10	5.0E-09	36.6	27.9	10.4	22.7
67	6.3E-09	2.7E-10	1.3E-09	2.1E-08	172.5	95.0	43.6	71.7
68	7.8E-09	3.2E-10	1.6E-09	2.6E-08	197.0	106.2	51.3	82.1
69	6.0E-09	2.5E-10	1.3E-09	2.0E-08	167.2	92.6	41.8	69.1
70	5.7E-09	2.5E-10	1.3E-09	2.0E-08	161.0	91.5	41.3	68.5
71	9.9E-09	4.0E-10	2.0E-09	3.0E-08	208.7	108.2	56.6	84.6
72	2.1E-08	1.1E-09	5.3E-09	7.4E-08	347.3	180.3	114.8	148.5
73	1.7E-08	9.1E-10	4.4E-09	5.6E-08	224.4	108.6	76.3	59.7
74	1.6E-09	1.9E-10	9.3E-10	1.4E-08	58.5	76.2	32.2	53.1
75	7.0E-09	1.1E-10	5.2E-10	8.0E-09	137.7	41.3	17.6	29.5
76	1.6E-08	1.3E-10	6.5E-10	8.6E-09	116.2	30.0	16.9	12.3
77	1.7E-09	3.7E-11	2.0E-10	3.4E-09	59.2	19.9	7.7	15.3
78	6.6E-09	1.1E-10	5.6E-10	8.5E-09	138.4	44.4	19.2	31.7
79	5.3E-09	8.9E-11	4.5E-10	6.9E-09	122.6	37.7	15.8	26.8
80	5.9E-09	1.0E-10	5.0E-10	7.6E-09	130.1	41.3	17.4	29.0
81	6.6E-09	1.1E-10	5.6E-10	8.4E-09	138.4	44.4	19.2	31.3
82	1.5E-08	1.5E-10	7.5E-10	9.8E-09	124.2	35.3	19.8	14.1
83	1.8E-08	1.9E-10	9.1E-10	1.2E-08	128.9	38.1	22.4	16.5
84	1.5E-08	1.6E-10	7.6E-10	1.0E-08	123.7	36.4	20.2	14.5
85	1.5E-08	1.6E-10	7.6E-10	1.0E-08	125.6	36.4	20.2	14.6
86	1.1E-08	2.1E-10	1.0E-09	1.3E-08	143.5	52.5	28.4	19.8
87	4.0E-09	1.4E-10	7.2E-10	1.2E-08	125.0	63.6	26.1	49.6
88	4.4E-09	1.5E-10	7.9E-10	1.4E-08	134.7	68.5	28.3	54.3
89	2.6E-09	8.0E-11	4.0E-10	6.4E-09	83.5	38.8	14.8	27.0
90	1.1E-08	2.2E-10	1.1E-09	1.4E-08	143.3	54.4	29.0	20.3
91	1.1E-08	3.5E-10	1.8E-09	2.7E-08	224.8	101.4	51.8	78.8
92	7.4E-09	2.7E-10	1.4E-09	2.2E-08	183.6	94.0	43.7	72.3
93	3.3E-09	1.1E-10	5.4E-10	8.1E-09	96.2	46.7	19.3	32.3

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
94	1.1E-08	3.8E-10	1.9E-09	2.9E-08	216.1	104.1	54.4	82.2
95	1.3E-08	4.2E-10	2.1E-09	3.2E-08	227.9	109.4	58.8	87.2
96	1.3E-08	4.2E-10	2.1E-09	3.2E-08	227.3	109.7	58.8	87.5
97	9.3E-09	2.3E-10	1.1E-09	1.4E-08	143.8	58.2	30.7	21.3
98	1.1E-08	3.8E-10	1.9E-09	2.9E-08	212.5	105.3	54.3	82.5
99	8.8E-09	2.3E-10	1.1E-09	1.5E-08	143.9	59.6	31.2	21.9
100	1.1E-08	4.1E-10	2.1E-09	3.2E-08	221.7	109.6	58.3	87.0
101	1.0E-08	3.7E-10	1.9E-09	2.9E-08	209.0	105.7	54.5	82.8
102	1.1E-09	5.8E-11	3.0E-10	5.7E-09	42.3	31.5	11.5	25.7
103	1.3E-09	6.9E-11	3.6E-10	6.8E-09	49.6	36.9	13.8	30.2
104	2.8E-09	1.3E-10	6.8E-10	1.2E-08	96.3	62.1	24.9	48.2
105	3.4E-09	1.6E-10	8.1E-10	1.4E-08	112.0	71.2	29.2	55.6
106	7.0E-09	2.9E-10	1.5E-09	2.3E-08	181.7	99.0	46.5	76.5
107	7.8E-09	3.1E-10	1.6E-09	2.5E-08	193.5	104.3	49.8	81.2
108	9.8E-09	3.7E-10	1.8E-09	2.8E-08	206.6	104.9	53.6	82.2
109	1.1E-08	4.1E-10	2.0E-09	3.1E-08	217.2	110.6	58.0	87.1
110	1.3E-08	4.9E-10	2.4E-09	3.7E-08	237.0	119.2	65.8	96.4
111	9.2E-09	2.6E-10	1.3E-09	1.6E-08	148.4	63.5	34.2	24.0
112	1.1E-09	5.9E-11	3.1E-10	5.9E-09	42.9	31.9	11.9	26.5
113	6.9E-09	2.8E-10	1.4E-09	2.3E-08	174.6	96.9	46.0	74.8
114	8.4E-09	3.4E-10	1.7E-09	2.8E-08	196.7	108.5	53.2	85.8
115	8.5E-09	3.5E-10	1.8E-09	2.8E-08	197.7	109.7	54.1	86.2
116	9.3E-09	3.8E-10	2.0E-09	3.1E-08	207.3	114.6	58.0	91.5
117	1.2E-08	4.8E-10	2.4E-09	3.9E-08	234.0	127.7	67.9	104.3
118	9.5E-09	3.6E-10	1.8E-09	2.8E-08	203.9	104.9	53.7	81.8
119	8.2E-09	2.3E-10	1.1E-09	1.5E-08	143.0	61.6	32.0	22.3
120	1.0E-08	2.9E-10	1.4E-09	1.8E-08	156.2	67.1	37.0	26.2
121	6.9E-09	2.8E-10	1.4E-09	2.3E-08	173.4	97.2	45.7	75.0
122	9.4E-09	3.6E-10	1.8E-09	2.8E-08	204.3	105.2	54.1	82.1
123	1.0E-08	4.0E-10	2.0E-09	3.1E-08	214.7	111.0	58.0	87.3
124	6.5E-09	2.9E-10	1.5E-09	2.4E-08	174.2	101.7	47.6	78.5
125	1.0E-08	4.3E-10	2.2E-09	3.3E-08	215.7	115.0	61.0	91.4
126	9.2E-09	2.8E-10	1.4E-09	1.8E-08	153.8	68.0	37.2	26.2

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
127	7.4E-09	2.3E-10	1.1E-09	1.5E-08	140.5	63.2	32.7	22.6
128	5.0E-09	2.4E-10	1.2E-09	1.9E-08	145.3	89.4	40.0	67.8
129	6.1E-09	2.9E-10	1.5E-09	2.4E-08	169.1	102.1	47.7	78.3
130	2.8E-08	9.2E-10	4.4E-09	5.9E-08	219.7	97.2	70.7	58.4
131	3.0E-08	5.4E-10	2.6E-09	3.0E-08	178.6	59.8	43.1	32.6
132	1.6E-08	6.6E-10	3.3E-09	4.8E-08	235.3	120.8	74.8	100.4
133	7.6E-09	3.4E-10	1.7E-09	2.6E-08	185.4	104.6	51.8	80.4
134	2.7E-08	9.2E-10	4.5E-09	5.8E-08	219.7	98.7	72.3	57.4
135	5.7E-09	3.1E-10	1.6E-09	2.4E-08	157.3	101.0	48.8	76.5
136	9.6E-10	6.8E-11	3.5E-10	6.1E-09	36.5	36.0	13.4	27.1
137	2.3E-08	9.6E-10	4.6E-09	6.1E-08	214.3	103.2	74.8	61.0
138	2.7E-08	1.2E-09	5.6E-09	7.4E-08	224.6	105.5	80.5	67.3
139	2.1E-08	8.9E-10	4.4E-09	5.6E-08	224.6	104.7	75.3	58.8
140	2.4E-08	1.1E-09	5.6E-09	7.3E-08	227.1	108.7	82.8	68.2
141	1.8E-08	8.7E-10	4.2E-09	5.6E-08	224.0	106.4	74.9	59.5
142	4.0E-11	5.0E-12	2.0E-11	6.0E-10	1.6	2.9	0.8	2.9
143	1.6E-10	1.9E-11	1.0E-10	1.9E-09	6.3	10.9	3.9	9.0
144	5.0E-10	5.0E-11	2.6E-10	4.5E-09	19.4	27.0	10.0	20.4
145	1.4E-08	8.8E-10	4.3E-09	5.5E-08	221.9	114.6	78.8	61.1
146	2.0E-11	4.0E-12	2.0E-11	4.0E-10	0.8	2.3	0.8	1.9
147	7.7E-10	9.7E-11	4.9E-10	7.8E-09	29.3	47.3	18.1	33.1
148	1.2E-09	1.5E-10	7.4E-10	1.2E-08	43.7	65.5	26.5	47.2
149	1.4E-09	1.7E-10	8.3E-10	1.3E-08	51.8	69.9	29.1	49.0
150	1.7E-09	2.0E-10	9.9E-10	1.5E-08	60.8	79.1	33.9	56.2
151	9.2E-09	1.6E-10	8.0E-10	1.2E-08	147.6	53.7	25.3	39.8
152	1.5E-08	6.2E-10	3.1E-09	4.5E-08	231.3	120.3	72.8	99.6
153	1.5E-08	6.1E-10	3.1E-09	4.5E-08	229.8	120.0	72.7	99.8
154	3.2E-08	1.1E-09	5.6E-09	7.3E-08	216.2	102.7	78.7	65.2
155	1.3E-08	5.9E-10	2.9E-09	4.3E-08	222.4	121.5	71.8	99.5
156	2.4E-08	1.3E-09	6.5E-09	8.6E-08	326.6	162.9	114.2	91.1
157	1.1E-08	8.6E-10	4.2E-09	5.5E-08	204.7	117.8	80.2	62.3
158	5.1E-09	8.6E-11	4.3E-10	6.8E-09	121.1	37.9	15.3	27.0
159	2.1E-09	6.2E-11	3.3E-10	6.4E-09	73.2	33.2	12.6	28.4

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
160	4.1E-09	9.0E-11	4.6E-10	7.2E-09	112.0	40.5	16.5	29.0
161	4.6E-09	1.0E-10	5.1E-10	8.0E-09	119.4	44.5	18.1	31.7
162	5.0E-09	1.1E-10	5.6E-10	8.8E-09	127.6	48.1	19.7	34.2
163	8.6E-09	1.6E-10	7.7E-10	1.1E-08	141.4	51.1	24.1	36.5
164	1.2E-08	1.9E-10	9.3E-10	1.2E-08	138.6	49.0	26.1	18.5
165	1.3E-08	2.1E-10	1.0E-09	1.4E-08	142.8	51.3	28.0	20.1
166	1.5E-08	2.3E-10	1.1E-09	1.5E-08	146.1	53.3	29.9	21.5
167	4.5E-09	1.0E-10	5.1E-10	8.0E-09	118.3	44.1	18.1	31.7
168	5.0E-09	1.1E-10	5.6E-10	8.8E-09	126.9	48.1	19.7	34.2
169	1.2E-08	1.9E-10	9.3E-10	1.2E-08	138.7	49.6	26.1	18.5
170	1.3E-08	2.1E-10	1.0E-09	1.4E-08	143.3	51.6	28.3	20.1
171	1.5E-08	2.3E-10	1.1E-09	1.5E-08	147.0	53.9	29.9	21.9
172	1.2E-08	1.9E-10	9.3E-10	1.2E-08	139.5	49.6	26.1	18.5
173	8.7E-09	2.2E-10	1.1E-09	1.4E-08	141.8	58.9	30.3	21.4
174	2.3E-08	7.1E-10	3.5E-09	5.0E-08	233.3	107.9	71.3	92.6
175	2.1E-08	6.8E-10	3.4E-09	4.7E-08	218.6	106.3	69.8	89.4
176	2.3E-08	7.6E-10	3.8E-09	5.3E-08	223.3	109.5	73.5	93.3
177	2.8E-08	8.5E-10	4.1E-09	5.6E-08	216.0	97.0	69.2	56.3
178	1.9E-08	4.0E-10	1.9E-09	2.4E-08	202.1	76.5	45.6	32.6
179	1.9E-08	6.3E-10	3.1E-09	4.4E-08	228.0	107.5	68.3	89.6
180	8.6E-09	3.7E-10	1.9E-09	2.9E-08	198.6	109.2	55.7	86.6
181	2.6E-08	8.4E-10	4.1E-09	5.5E-08	217.5	98.6	70.4	56.4
182	3.2E-08	1.0E-09	5.1E-09	6.8E-08	228.4	103.0	76.5	63.6
183	6.6E-09	2.9E-10	1.5E-09	2.3E-08	170.6	97.3	46.1	74.5
184	8.1E-09	3.6E-10	1.8E-09	2.9E-08	194.3	109.1	55.0	85.9
185	2.0E-08	7.4E-10	3.7E-09	5.2E-08	225.1	112.1	74.1	95.6
186	1.8E-08	6.8E-10	3.4E-09	4.8E-08	232.9	112.2	72.2	94.3
187	2.8E-08	9.3E-10	4.5E-09	6.1E-08	224.2	101.3	73.4	60.4
188	3.1E-08	1.0E-09	5.0E-09	6.8E-08	230.6	104.4	76.8	64.2
189	2.2E-08	8.2E-10	4.0E-09	5.7E-08	231.2	115.6	77.8	99.0
190	1.8E-08	6.7E-10	3.3E-09	4.6E-08	218.0	109.9	70.2	91.5
191	2.7E-08	9.0E-10	4.4E-09	5.9E-08	207.0	98.9	71.8	59.0
192	7.0E-09	3.2E-10	1.6E-09	2.5E-08	176.6	102.2	49.7	79.6

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
193	2.3E-08	8.4E-10	4.1E-09	5.5E-08	220.8	101.2	71.8	57.6
194	2.6E-08	9.3E-10	4.5E-09	6.0E-08	225.2	103.4	74.9	60.5
195	1.9E-08	7.9E-10	3.9E-09	5.5E-08	229.7	117.3	77.8	100.0
196	2.2E-08	8.3E-10	4.0E-09	5.4E-08	221.6	103.8	72.3	58.1
197	1.5E-08	6.4E-10	3.1E-09	4.4E-08	214.0	111.5	69.6	92.3
198	1.8E-08	7.8E-10	3.9E-09	5.5E-08	230.4	117.5	78.2	100.7
199	2.8E-08	1.1E-09	5.3E-09	7.1E-08	219.7	105.9	78.9	66.4
200	2.1E-08	8.2E-10	4.0E-09	5.4E-08	222.4	103.3	72.6	57.9
201	2.6E-08	1.0E-09	5.0E-09	6.6E-08	233.6	108.8	79.2	64.7
202	2.6E-08	1.0E-09	5.0E-09	6.6E-08	233.6	107.5	79.2	64.7
203	1.6E-08	3.8E-10	1.8E-09	2.0E-08	109.5	42.2	30.0	21.7
204	2.7E-08	1.1E-09	5.3E-09	7.0E-08	220.2	105.9	80.0	65.4
205	1.4E-08	6.3E-10	3.1E-09	4.4E-08	211.6	112.5	69.7	92.4
206	2.2E-08	8.8E-10	4.3E-09	5.7E-08	210.7	103.6	73.8	58.5
207	2.0E-08	8.1E-10	4.0E-09	5.3E-08	221.5	104.1	72.7	57.1
208	2.2E-08	9.1E-10	4.4E-09	6.0E-08	227.8	107.6	75.6	61.8
209	6.1E-08	1.5E-09	7.0E-09	7.8E-08	137.7	49.5	44.3	40.2
210	7.1E-08	1.6E-09	7.1E-09	7.4E-08	115.7	35.7	32.9	30.6
211	1.6E-08	7.7E-10	3.8E-09	5.1E-08	218.0	107.2	72.7	57.1
212	1.6E-08	7.7E-10	3.8E-09	5.1E-08	219.2	107.8	73.0	57.4
213	4.6E-08	1.7E-09	8.0E-09	1.0E-07	311.4	127.9	100.8	83.3
214	1.5E-08	7.6E-10	3.7E-09	5.0E-08	215.5	108.9	72.5	57.3
215	3.8E-08	1.4E-09	6.8E-09	8.1E-08	172.6	74.5	63.0	54.7
216	4.1E-08	1.7E-09	8.0E-09	1.0E-07	296.4	134.1	104.5	88.0
217	6.2E-08	2.1E-09	9.8E-09	1.2E-07	225.2	94.1	81.0	71.2
218	1.3E-08	7.3E-10	3.6E-09	4.7E-08	211.2	110.0	72.2	55.7
219	1.4E-08	8.0E-10	3.9E-09	5.3E-08	217.6	112.3	75.5	59.9
220	5.7E-08	2.0E-09	9.5E-09	1.1E-07	265.3	102.0	86.4	74.2
221	1.1E-08	6.9E-10	3.4E-09	4.6E-08	202.2	110.5	70.9	55.2
222	1.0E-08	6.7E-10	3.3E-09	4.3E-08	194.8	110.6	70.4	53.1
223	2.3E-08	1.4E-09	6.7E-09	9.0E-08	332.2	170.5	118.5	95.5
224	8.1E-08	2.2E-09	1.0E-08	1.1E-07	144.2	46.9	43.6	40.8
225	1.0E-07	2.7E-09	1.3E-08	1.3E-07	145.6	47.3	45.2	42.2

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
226	1.9E-09	1.8E-10	8.9E-10	1.4E-08	66.1	73.1	30.8	53.2
227	8.7E-09	6.3E-10	3.1E-09	4.1E-08	183.3	110.2	68.5	52.1
228	4.4E-09	3.9E-10	1.9E-09	2.7E-08	127.5	103.4	54.4	78.4
229	8.4E-10	1.0E-10	5.2E-10	8.1E-09	31.7	47.7	19.0	33.6
230	8.7E-10	1.1E-10	5.7E-10	9.0E-09	32.7	51.6	20.5	36.4
231	1.2E-09	4.6E-11	2.5E-10	4.9E-09	44.6	25.3	9.7	22.3
232	3.0E-08	9.9E-10	4.9E-09	6.9E-08	364.1	163.7	104.7	136.7
233	1.9E-08	7.7E-10	3.8E-09	5.4E-08	229.4	116.8	76.8	98.9
234	4.3E-08	1.4E-09	6.5E-09	7.8E-08	163.3	70.3	59.1	51.7
235	4.0E-08	1.4E-09	6.7E-09	9.1E-08	311.8	146.8	106.7	88.3
236	1.9E-08	8.2E-10	4.0E-09	5.4E-08	210.1	105.9	73.0	58.7
237	1.8E-08	7.6E-10	3.7E-09	5.0E-08	219.9	106.4	71.7	56.5
238	1.8E-08	8.0E-10	4.0E-09	5.3E-08	230.8	108.4	74.5	58.7
239	7.0E-08	1.9E-09	8.9E-09	1.1E-07	237.6	91.7	77.4	67.5
240	4.6E-08	1.7E-09	8.2E-09	1.0E-07	278.7	126.9	100.5	83.9
241	1.5E-09	1.1E-10	5.5E-10	9.3E-09	52.9	51.9	20.1	38.6
242	5.7E-08	1.9E-09	9.3E-09	1.1E-07	264.1	102.1	86.9	75.0
243	7.0E-08	2.4E-09	1.1E-08	1.3E-07	270.5	104.0	89.6	78.7
244	9.6E-08	2.0E-09	9.1E-09	9.5E-08	149.2	43.9	40.8	37.8
245	2.3E-08	1.1E-09	5.6E-09	7.5E-08	344.8	162.9	109.4	85.9
246	1.2E-08	7.2E-10	3.5E-09	4.7E-08	198.4	109.5	71.8	55.8
247	4.9E-08	1.9E-09	9.2E-09	1.1E-07	258.6	112.4	93.3	80.0
248	4.1E-09	3.4E-10	1.7E-09	2.4E-08	119.8	96.6	49.3	72.9
249	4.9E-08	2.4E-09	1.1E-08	1.3E-07	313.5	121.0	101.8	88.7
250	5.8E-08	2.3E-09	1.1E-08	1.2E-07	242.0	83.9	75.0	65.4
251	2.5E-08	3.2E-10	1.5E-09	1.9E-08	106.5	40.3	28.0	21.1
252	4.5E-08	1.3E-09	6.4E-09	7.7E-08	159.9	70.9	59.8	51.7
253	4.9E-08	1.7E-09	7.9E-09	9.5E-08	172.2	75.5	64.8	57.2
254	4.8E-08	1.7E-09	7.9E-09	9.5E-08	172.7	75.8	65.3	57.2
255	3.3E-08	1.2E-09	5.9E-09	7.4E-08	183.4	82.7	66.5	56.9
256	9.5E-08	2.3E-09	1.1E-08	1.1E-07	139.0	47.1	43.9	41.3
257	2.8E-08	2.3E-09	1.1E-08	1.1E-07	182.8	64.1	58.8	53.3
258	2.5E-08	2.3E-10	1.1E-09	1.3E-08	80.0	25.8	18.6	14.1

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
259	1.8E-08	2.7E-10	1.3E-09	1.6E-08	117.0	42.9	27.3	19.9
260	3.6E-08	2.8E-10	1.3E-09	1.5E-08	110.2	30.1	21.8	16.4
261	2.4E-08	2.5E-10	1.2E-09	1.4E-08	83.2	28.0	20.1	15.0
262	2.6E-08	2.8E-10	1.3E-09	1.6E-08	84.0	28.8	21.2	16.5
263	2.3E-08	2.7E-10	1.2E-09	1.5E-08	83.6	29.3	20.7	16.2
264	2.9E-08	3.2E-10	1.5E-09	1.7E-08	85.5	29.9	22.4	17.4
265	2.4E-08	2.6E-10	1.2E-09	1.4E-08	84.2	29.1	20.5	15.0
266	2.8E-08	3.2E-10	1.5E-09	1.7E-08	95.9	31.1	23.6	17.9
267	1.8E-08	3.4E-10	1.6E-09	1.9E-08	100.5	37.9	27.3	20.7
268	6.1E-08	1.5E-09	7.3E-09	8.8E-08	166.9	69.7	60.3	53.0
269	5.8E-08	1.5E-09	7.3E-09	8.9E-08	170.6	71.2	60.8	54.3
270	2.1E-08	4.4E-10	2.1E-09	2.4E-08	107.2	41.9	31.4	24.4
271	6.5E-08	1.4E-09	6.8E-09	7.6E-08	121.0	48.8	44.2	39.2
272	3.9E-08	1.2E-09	5.6E-09	7.0E-08	185.6	80.1	63.8	54.7
273	6.2E-08	1.4E-09	6.7E-09	7.6E-08	136.8	51.6	45.6	40.9
274	2.4E-09	1.3E-10	6.7E-10	1.1E-08	83.3	59.4	24.2	45.6
275	3.6E-08	1.2E-09	5.6E-09	7.0E-08	181.3	83.3	66.5	56.0
276	6.2E-08	1.5E-09	6.9E-09	7.8E-08	124.4	49.8	45.1	40.4
277	2.2E-08	8.8E-10	4.3E-09	5.9E-08	230.6	110.1	77.1	62.4
278	6.1E-08	1.5E-09	6.9E-09	7.9E-08	125.9	50.3	45.1	41.1
279	7.3E-08	1.8E-09	8.4E-09	9.5E-08	142.2	53.3	48.6	44.2
280	3.4E-09	1.9E-10	9.7E-10	1.7E-08	110.4	79.1	33.7	61.6
281	3.0E-08	1.0E-09	5.1E-09	6.5E-08	193.5	91.2	70.1	57.5
282	6.1E-08	1.5E-09	7.0E-09	7.9E-08	127.4	51.4	46.1	41.1
283	2.2E-09	1.2E-10	6.2E-10	1.1E-08	75.0	56.0	22.5	43.3
284	4.5E-08	1.4E-09	6.7E-09	8.2E-08	180.7	75.3	63.2	55.4
285	6.0E-08	1.5E-09	7.0E-09	8.0E-08	128.0	51.9	46.1	41.9
286	6.6E-08	1.7E-09	7.7E-09	8.7E-08	128.5	52.1	46.4	42.0
287	6.4E-08	1.6E-09	7.6E-09	8.7E-08	143.3	54.3	48.1	43.9
288	7.1E-08	1.8E-09	8.5E-09	9.7E-08	143.4	54.4	49.4	45.5
289	7.4E-08	1.9E-09	8.9E-09	1.0E-07	144.1	54.7	50.0	45.5
290	2.8E-08	1.0E-09	5.1E-09	6.5E-08	194.5	92.9	70.9	58.0
291	5.9E-08	1.5E-09	7.1E-09	8.0E-08	130.6	51.9	47.0	41.9

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
292	7.3E-08	1.5E-09	6.8E-09	7.2E-08	98.1	34.8	32.4	29.9
293	7.3E-08	1.5E-09	6.8E-09	7.2E-08	111.0	36.5	33.5	30.9
294	1.8E-08	7.5E-10	3.7E-09	5.1E-08	208.2	105.6	71.4	57.0
295	5.7E-08	1.5E-09	7.1E-09	8.1E-08	130.6	53.0	47.0	42.6
296	5.5E-08	1.5E-09	7.1E-09	8.0E-08	144.4	54.8	49.7	44.0
297	1.7E-08	7.4E-10	3.6E-09	5.0E-08	207.7	105.4	70.8	56.9
298	1.6E-08	6.8E-10	3.4E-09	4.7E-08	213.9	104.6	68.9	54.9
299	5.7E-08	1.5E-09	7.1E-09	8.0E-08	131.3	53.2	47.3	42.1
300	6.6E-08	1.9E-09	8.8E-09	9.9E-08	135.7	54.9	50.0	45.4
301	3.0E-08	1.2E-09	6.0E-09	7.8E-08	207.7	97.6	76.7	65.0
302	4.5E-08	1.6E-09	7.7E-09	9.4E-08	176.2	78.3	66.4	58.8
303	3.5E-08	1.3E-09	6.0E-09	7.3E-08	187.1	78.3	64.5	54.5
304	4.3E-08	1.6E-09	7.4E-09	9.0E-08	191.9	79.9	67.9	59.2
305	5.2E-08	1.6E-09	7.3E-09	8.3E-08	138.5	56.3	49.7	44.6
306	6.4E-08	1.9E-09	9.0E-09	1.0E-07	140.1	56.7	51.4	46.5
307	8.3E-08	1.9E-09	9.0E-09	9.4E-08	108.4	38.0	36.1	33.5
308	6.7E-08	1.6E-09	7.4E-09	7.8E-08	108.1	38.3	35.7	32.8
309	1.5E-09	9.7E-11	5.0E-10	8.6E-09	52.7	46.9	18.5	36.0
310	1.4E-08	7.0E-10	3.5E-09	4.8E-08	205.0	106.7	70.6	55.7
311	4.7E-08	1.6E-09	7.8E-09	9.9E-08	295.6	121.8	96.5	81.1
312	2.7E-08	1.1E-09	5.4E-09	6.9E-08	192.3	88.8	69.9	59.0
313	5.2E-08	1.7E-09	8.2E-09	1.0E-07	284.7	114.7	92.4	79.2
314	3.0E-08	1.2E-09	5.7E-09	7.2E-08	185.9	85.1	67.7	57.6
315	3.3E-08	1.3E-09	6.0E-09	7.4E-08	188.7	79.7	65.2	56.1
316	5.1E-08	1.6E-09	7.4E-09	8.3E-08	139.5	56.5	50.7	44.6
317	8.9E-08	1.4E-09	6.5E-09	6.4E-08	83.2	20.9	20.3	19.7
318	4.8E-08	1.5E-09	7.2E-09	8.2E-08	156.2	59.7	52.2	46.6
319	4.4E-08	1.6E-09	7.6E-09	8.5E-08	150.0	60.8	54.3	47.5
320	4.4E-08	1.6E-09	7.6E-09	8.5E-08	150.7	60.8	54.3	47.5
321	2.6E-08	3.6E-10	1.6E-09	1.6E-08	81.1	19.9	16.0	13.1
322	4.2E-08	1.6E-09	7.4E-09	8.3E-08	166.0	63.4	56.1	48.8
323	4.2E-08	1.6E-09	7.5E-09	8.6E-08	153.1	61.5	54.0	48.6
324	8.7E-10	7.2E-11	3.7E-10	6.4E-09	32.7	36.2	13.9	27.6

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
325	4.2E-08	1.6E-09	7.6E-09	8.5E-08	153.7	61.8	55.1	48.0
326	8.7E-08	2.1E-09	9.6E-09	1.0E-07	136.2	47.0	43.6	40.1
327	1.1E-07	1.5E-09	6.7E-09	6.6E-08	105.0	22.1	21.1	20.6
328	4.0E-08	1.6E-09	7.7E-09	8.6E-08	158.0	63.6	57.0	49.4
329	7.0E-10	6.4E-11	3.3E-10	5.6E-09	26.6	32.8	12.5	24.5
330	3.8E-08	1.6E-09	7.6E-09	8.6E-08	160.3	64.8	56.7	50.0
331	4.7E-08	2.0E-09	9.4E-09	1.1E-07	162.6	65.1	59.1	52.5
332	8.2E-08	2.2E-09	1.0E-08	1.1E-07	144.7	50.1	46.5	43.1
333	9.1E-08	2.4E-09	1.1E-08	1.2E-07	146.0	50.3	47.1	43.7
334	6.5E-08	2.2E-09	1.0E-08	1.1E-07	128.6	45.6	42.8	40.1
335	5.7E-08	2.0E-09	9.0E-09	9.5E-08	141.1	47.6	43.7	40.1
336	9.5E-08	1.6E-09	7.3E-09	7.1E-08	94.1	24.1	23.2	22.1
337	9.8E-09	6.5E-10	3.2E-09	4.3E-08	187.9	110.3	69.5	53.5
338	1.7E-08	9.5E-10	4.6E-09	5.9E-08	205.7	96.7	71.3	58.4
339	3.8E-08	1.6E-09	7.6E-09	8.6E-08	160.5	64.4	56.7	50.0
340	9.8E-08	2.7E-09	1.3E-08	1.3E-07	177.7	54.9	51.4	48.2
341	2.8E-08	2.7E-10	1.2E-09	1.2E-08	67.5	10.9	9.4	8.5
342	3.3E-08	1.6E-09	7.6E-09	8.5E-08	170.3	67.8	59.8	51.5
343	8.9E-08	2.9E-09	1.3E-08	1.4E-07	161.8	56.0	52.2	49.1
344	8.0E-08	2.6E-09	1.2E-08	1.3E-07	164.5	56.5	52.8	48.7
345	5.0E-09	4.3E-10	2.1E-09	2.9E-08	135.1	97.0	54.8	40.6
346	1.0E-08	7.7E-10	3.7E-09	4.9E-08	182.1	102.9	70.1	54.8
347	2.6E-08	1.6E-09	7.5E-09	9.5E-08	332.3	146.2	110.3	89.6
348	1.3E-08	9.0E-10	4.4E-09	5.5E-08	190.0	98.7	72.7	56.9
349	3.4E-08	1.9E-09	8.8E-09	1.1E-07	278.9	120.9	98.2	83.7
350	2.0E-08	1.3E-09	6.4E-09	7.8E-08	211.7	94.4	75.5	63.4
351	1.7E-08	1.1E-09	5.2E-09	6.3E-08	201.0	91.6	71.0	57.3
352	6.3E-08	2.8E-09	1.3E-08	1.5E-07	228.8	88.6	79.5	72.0
353	5.1E-08	2.3E-09	1.1E-08	1.2E-07	224.7	87.7	77.7	68.5
354	4.8E-08	2.2E-09	1.0E-08	1.2E-07	261.1	92.4	81.3	70.5
355	3.2E-08	1.8E-09	8.3E-09	9.3E-08	176.4	70.6	62.4	54.4
356	8.3E-08	3.0E-09	1.4E-08	1.4E-07	171.2	59.1	55.5	51.6
357	6.7E-08	2.4E-09	1.1E-08	1.2E-07	168.8	58.3	53.9	49.8

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
358	6.8E-08	2.4E-09	1.1E-08	1.2E-07	171.4	58.9	53.9	49.8
359	7.5E-08	2.7E-09	1.2E-08	1.3E-07	171.7	58.8	55.1	50.6
360	8.4E-08	3.0E-09	1.4E-08	1.4E-07	173.3	59.1	55.5	51.6
361	4.2E-08	1.9E-09	8.6E-09	9.1E-08	143.3	51.1	46.5	42.3
362	4.1E-08	1.8E-09	8.5E-09	9.0E-08	157.1	53.0	48.3	43.7
363	9.0E-08	1.5E-09	6.7E-09	6.4E-08	90.3	18.5	18.0	17.8
364	2.0E-08	1.3E-09	6.4E-09	7.8E-08	212.4	94.4	75.5	63.4
365	8.3E-08	3.0E-09	1.4E-08	1.4E-07	171.2	59.1	55.5	51.6
366	1.9E-08	1.4E-09	6.5E-09	7.9E-08	203.5	94.4	76.4	63.7
367	2.5E-08	1.6E-09	7.3E-09	8.3E-08	180.7	73.2	62.4	54.2
368	2.8E-08	1.7E-09	8.2E-09	9.1E-08	181.7	73.5	65.1	55.5
369	2.4E-08	1.5E-09	7.0E-09	8.0E-08	189.7	74.9	63.6	55.2
370	2.7E-08	1.7E-09	7.8E-09	8.8E-08	193.4	75.7	65.5	56.8
371	3.5E-09	3.7E-10	1.8E-09	2.5E-08	104.5	91.2	49.6	36.7
372	3.3E-08	1.9E-09	8.8E-09	9.2E-08	158.9	56.1	51.5	45.8
373	1.8E-08	1.4E-09	6.6E-09	8.3E-08	288.3	147.8	106.5	85.1
374	5.3E-08	2.5E-09	1.2E-08	1.2E-07	231.3	72.2	65.7	59.6
375	5.6E-08	2.9E-09	1.3E-08	1.4E-07	206.3	70.4	65.2	59.6
376	7.3E-08	3.7E-09	1.7E-08	1.8E-07	212.0	71.3	67.6	62.8
377	5.5E-08	2.9E-09	1.3E-08	1.4E-07	208.8	71.4	66.3	60.5
378	2.6E-08	1.9E-09	8.7E-09	9.1E-08	168.8	61.3	55.4	48.7
379	1.8E-08	1.8E-09	8.1E-09	8.6E-08	177.8	66.5	58.7	51.8
380	2.8E-08	2.6E-09	1.2E-08	1.3E-07	254.1	88.9	79.3	69.8
381	1.8E-08	2.1E-09	9.6E-09	1.0E-07	187.2	69.2	62.3	55.5
382	2.7E-08	2.2E-10	1.0E-09	1.1E-08	65.6	19.3	14.4	11.8
383	2.6E-08	2.3E-10	1.1E-09	1.2E-08	68.6	20.0	15.7	13.6
384	3.1E-08	3.0E-10	1.4E-09	1.6E-08	77.8	22.6	18.0	15.7
385	2.5E-08	2.4E-10	1.1E-09	1.2E-08	68.5	20.9	16.0	13.4
386	2.8E-08	2.7E-10	1.3E-09	1.3E-08	69.1	21.6	16.6	13.9
387	5.8E-09	1.9E-10	9.8E-10	1.7E-08	155.0	80.9	33.7	91.0
388	8.3E-08	1.6E-09	7.2E-09	7.8E-08	108.1	36.5	33.5	32.6
389	2.2E-09	1.2E-10	6.2E-10	1.1E-08	76.6	59.0	22.5	67.7
390	2.5E-09	1.3E-10	6.9E-10	1.2E-08	83.4	63.0	24.9	73.3

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
391	7.1E-08	1.5E-09	6.9E-09	7.4E-08	102.9	37.4	34.2	32.7
392	7.0E-08	1.5E-09	6.9E-09	7.4E-08	115.6	39.0	35.6	33.9
393	4.6E-08	1.6E-09	7.4E-09	9.2E-08	174.4	78.7	66.1	62.2
394	6.6E-08	1.8E-09	8.7E-09	1.0E-07	137.9	57.3	51.5	49.3
395	6.9E-08	1.5E-09	7.0E-09	7.6E-08	104.9	38.4	34.8	33.8
396	7.6E-08	1.7E-09	7.8E-09	8.4E-08	104.7	38.1	35.5	34.4
397	3.6E-08	1.3E-09	6.0E-09	7.4E-08	171.4	78.3	63.8	57.8
398	6.7E-08	1.5E-09	7.2E-09	7.7E-08	105.7	39.0	36.0	34.4
399	6.7E-08	1.6E-09	7.2E-09	7.7E-08	107.7	39.3	36.0	34.4
400	7.5E-08	2.0E-09	9.2E-09	9.9E-08	115.4	42.2	39.0	37.9
401	5.1E-08	1.8E-09	8.4E-09	1.1E-07	274.3	111.3	90.2	83.3
402	7.4E-08	2.3E-09	1.0E-08	1.1E-07	156.3	56.0	51.0	49.1
403	3.2E-08	1.5E-09	7.0E-09	8.0E-08	180.6	70.5	60.3	55.2
404	3.5E-08	1.6E-09	7.8E-09	9.0E-08	183.8	71.0	61.9	58.1
405	8.3E-08	2.5E-09	1.2E-08	1.2E-07	158.6	56.1	52.0	50.0
406	6.1E-08	2.4E-09	1.1E-08	1.2E-07	182.3	65.2	59.2	56.3
407	6.7E-08	2.7E-09	1.3E-08	1.3E-07	184.2	65.0	59.8	57.5
408	4.6E-08	2.2E-09	1.0E-08	1.1E-07	153.2	55.4	51.0	48.7
409	3.7E-08	1.8E-09	8.5E-09	9.1E-08	150.8	55.0	50.0	47.2
410	1.8E-08	1.2E-09	6.0E-09	7.3E-08	206.7	93.9	74.1	67.0
411	5.5E-08	2.7E-09	1.3E-08	1.5E-07	244.4	96.4	85.3	80.2
412	7.5E-08	3.0E-09	1.4E-08	1.5E-07	186.1	65.2	60.7	58.3
413	1.0E-07	4.1E-09	1.9E-08	2.0E-07	188.9	66.9	62.9	61.7
414	5.9E-08	2.4E-09	1.1E-08	1.2E-07	216.5	69.9	62.9	59.7
415	3.7E-08	1.8E-09	8.5E-09	9.1E-08	150.8	55.3	50.0	47.2
416	3.7E-08	1.8E-09	8.4E-09	9.0E-08	151.8	54.5	49.1	46.4
417	4.1E-08	2.0E-09	9.4E-09	1.0E-07	152.2	54.9	50.5	47.6
418	4.6E-08	2.2E-09	1.0E-08	1.1E-07	154.4	55.4	51.0	49.3
419	4.4E-08	2.2E-09	1.0E-08	1.1E-07	168.2	57.5	52.8	50.9
420	3.3E-08	1.8E-09	8.5E-09	9.1E-08	157.8	57.5	51.8	48.7
421	2.4E-08	1.6E-09	7.5E-09	8.6E-08	186.5	77.2	65.8	60.6
422	2.8E-08	1.8E-09	8.4E-09	9.0E-08	166.1	60.0	53.8	50.6
423	6.2E-08	2.5E-09	1.2E-08	1.1E-07	154.4	43.5	41.4	40.3

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
424	3.5E-08	2.8E-10	1.3E-09	1.5E-08	93.3	25.0	19.2	6.3
425	3.4E-08	3.0E-10	1.4E-09	1.6E-08	97.1	26.5	20.7	6.6
426	2.3E-08	2.8E-10	1.3E-09	1.4E-08	74.7	25.5	19.2	5.8
427	2.6E-08	1.8E-10	8.6E-10	9.0E-09	57.9	11.9	10.0	3.6
428	2.1E-08	3.7E-10	1.8E-09	2.4E-08	185.1	71.3	42.8	11.1
429	3.4E-08	3.1E-10	1.5E-09	1.6E-08	98.2	27.4	21.2	6.6
430	2.8E-08	3.4E-10	1.6E-09	1.8E-08	76.3	25.8	20.8	7.2
431	8.6E-09	2.6E-10	1.4E-09	2.5E-08	247.8	114.3	48.2	14.9
432	3.3E-08	3.2E-10	1.5E-09	1.7E-08	100.0	28.3	21.7	7.1
433	1.1E-07	1.7E-09	7.7E-09	8.5E-08	129.9	42.4	38.9	22.7
434	1.1E-07	1.7E-09	7.7E-09	8.5E-08	130.1	42.7	38.9	22.7
435	1.1E-07	1.7E-09	7.9E-09	8.6E-08	131.9	43.2	40.1	22.9
436	8.6E-08	1.8E-09	8.3E-09	9.1E-08	115.6	40.2	37.6	22.8
437	8.3E-08	1.8E-09	8.5E-09	9.3E-08	106.1	40.0	37.3	22.9
438	8.3E-08	1.8E-09	8.5E-09	9.3E-08	119.3	41.5	38.8	23.4
439	9.9E-08	1.8E-09	8.6E-09	9.5E-08	145.6	48.0	44.1	25.5
440	9.8E-08	1.9E-09	8.6E-09	9.5E-08	147.0	48.3	44.1	25.5
441	9.5E-08	1.9E-09	9.0E-09	9.7E-08	152.4	50.0	46.6	26.1
442	1.2E-07	2.4E-09	1.1E-08	1.2E-07	153.3	50.9	48.1	29.5
443	7.6E-08	1.9E-09	8.9E-09	9.7E-08	126.7	44.5	41.4	24.7
444	9.4E-08	1.9E-09	9.0E-09	9.9E-08	155.8	51.1	46.6	26.8
445	9.0E-08	2.4E-09	1.1E-08	1.3E-07	212.8	80.3	72.2	38.6
446	9.3E-08	1.9E-09	9.1E-09	9.9E-08	155.5	51.1	47.4	26.8
447	4.5E-08	1.5E-09	7.0E-09	8.1E-08	148.7	62.4	55.1	26.1
448	9.1E-08	2.0E-09	9.1E-09	1.0E-07	157.3	52.1	47.4	27.1
449	6.0E-08	1.6E-09	7.4E-09	8.1E-08	115.8	43.5	39.8	22.4
450	7.3E-08	2.0E-09	9.1E-09	1.0E-07	118.6	44.4	41.0	25.0
451	7.3E-08	2.0E-09	9.5E-09	1.1E-07	183.2	75.8	66.9	34.4
452	8.9E-08	2.0E-09	9.3E-09	1.0E-07	160.4	53.2	48.7	27.7
453	7.2E-08	2.0E-09	9.2E-09	1.0E-07	119.6	44.9	41.6	25.3
454	3.9E-08	1.5E-09	7.2E-09	9.3E-08	301.5	125.6	97.8	36.5
455	5.7E-08	1.6E-09	7.6E-09	8.4E-08	121.5	45.4	41.5	23.4
456	8.9E-08	2.0E-09	9.3E-09	1.0E-07	133.4	47.8	44.3	26.2

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
457	7.9E-08	2.5E-09	1.2E-08	1.4E-07	230.4	86.0	76.3	40.4
458	1.0E-07	2.5E-09	1.2E-08	1.3E-07	172.1	56.8	52.9	32.3
459	8.2E-08	2.1E-09	9.7E-09	1.1E-07	172.5	57.3	51.9	29.1
460	3.5E-08	1.4E-09	7.0E-09	9.1E-08	304.3	128.6	98.6	36.1
461	3.6E-08	1.4E-09	6.7E-09	7.8E-08	170.8	67.8	58.3	26.4
462	8.2E-08	2.1E-09	9.9E-09	1.1E-07	175.1	57.7	53.2	29.8
463	5.3E-08	1.7E-09	7.7E-09	8.5E-08	126.2	47.0	42.8	23.9
464	7.3E-08	1.5E-09	6.7E-09	6.8E-08	95.8	25.1	23.8	15.6
465	2.9E-08	1.4E-09	6.7E-09	8.6E-08	311.3	134.3	100.6	35.0
466	7.2E-08	2.2E-09	1.0E-08	1.1E-07	191.8	63.1	57.2	31.7
467	8.6E-08	2.7E-09	1.3E-08	1.4E-07	167.4	60.9	57.1	34.7
468	7.0E-08	2.2E-09	1.1E-08	1.2E-07	199.1	64.6	59.3	32.6
469	6.9E-08	2.2E-09	1.0E-08	1.1E-07	199.7	65.1	58.8	32.3
470	6.6E-08	2.3E-09	1.1E-08	1.2E-07	203.1	66.7	60.9	33.1
471	9.4E-08	2.0E-10	1.0E-09	1.2E-08	52.2	1.9	2.1	1.4
472	6.4E-08	2.3E-09	1.1E-08	1.2E-07	207.4	68.1	61.3	33.2
473	1.1E-07	3.8E-09	1.8E-08	2.0E-07	214.7	69.1	65.4	43.1
474	8.8E-08	2.0E-09	9.2E-09	9.1E-08	133.6	33.2	31.8	20.5
475	9.3E-08	9.5E-10	4.4E-09	4.1E-08	70.5	10.6	10.6	5.1
476	7.4E-08	1.2E-09	5.3E-09	5.0E-08	78.9	13.5	13.4	6.3
477	9.1E-08	1.4E-09	6.6E-09	6.1E-08	79.1	13.2	13.7	7.1
478	3.5E-08	1.8E-09	8.8E-09	1.1E-07	322.2	132.8	106.0	41.5
479	5.0E-08	2.2E-09	1.1E-08	1.2E-07	268.4	98.7	85.4	40.5
480	2.6E-08	1.3E-09	6.3E-09	7.5E-08	186.9	74.0	61.2	26.7
481	6.4E-08	2.3E-09	1.1E-08	1.2E-07	206.5	68.1	62.2	33.6
482	7.8E-08	2.8E-09	1.3E-08	1.4E-07	211.7	68.6	63.7	36.9
483	4.5E-08	1.9E-09	9.0E-09	9.8E-08	146.7	54.4	49.7	27.5
484	6.0E-08	1.7E-09	8.0E-09	8.0E-08	113.6	30.8	29.4	18.8
485	1.0E-07	1.6E-09	7.3E-09	7.0E-08	86.3	18.6	18.2	13.2
486	5.9E-08	2.3E-09	1.1E-08	1.2E-07	216.7	71.3	64.3	34.4
487	8.8E-08	1.1E-09	5.1E-09	4.9E-08	75.9	12.5	12.2	6.1
488	5.6E-08	2.3E-09	1.1E-08	1.2E-07	223.7	73.0	66.5	35.0
489	5.3E-08	2.3E-09	1.1E-08	1.2E-07	228.8	75.0	67.3	35.3

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
490	6.4E-08	3.0E-09	1.4E-08	1.5E-07	204.4	73.2	67.6	39.3
491	5.2E-08	2.4E-09	1.1E-08	1.2E-07	200.8	72.0	65.5	35.2
492	5.8E-08	2.7E-09	1.3E-08	1.4E-07	203.5	72.9	67.2	37.5
493	6.4E-08	2.9E-09	1.4E-08	1.5E-07	204.1	73.0	67.6	39.6
494	5.1E-08	2.3E-09	1.1E-08	1.2E-07	234.9	76.5	68.6	35.6
495	3.1E-08	1.7E-09	8.1E-09	8.9E-08	160.3	59.5	53.3	27.3
496	3.4E-08	1.9E-09	8.9E-09	9.7E-08	161.5	59.0	53.6	28.4
497	8.2E-08	2.5E-09	1.1E-08	1.1E-07	131.6	36.6	35.1	23.6
498	7.5E-08	2.3E-09	1.1E-08	1.1E-07	157.4	39.7	38.0	24.2
499	8.5E-08	1.4E-09	6.0E-09	5.6E-08	85.0	15.1	14.3	6.9
500	9.4E-08	1.5E-09	6.6E-09	6.2E-08	84.7	14.9	14.3	7.3
501	3.8E-08	2.1E-09	9.9E-09	1.1E-07	163.5	59.9	54.7	30.3
502	3.7E-08	2.0E-09	9.5E-09	1.0E-07	175.6	61.1	55.2	30.0
503	1.0E-07	1.6E-09	7.4E-09	6.9E-08	84.6	14.3	14.5	7.8
504	4.5E-08	2.3E-09	1.1E-08	1.2E-07	245.7	80.1	71.2	36.7
505	2.8E-08	1.7E-09	8.0E-09	8.7E-08	165.3	60.9	54.8	27.2
506	8.1E-08	1.5E-09	6.6E-09	6.2E-08	91.9	16.0	15.7	7.7
507	3.0E-08	1.9E-09	8.7E-09	9.6E-08	168.7	61.6	54.7	28.8
508	7.0E-08	2.3E-09	1.1E-08	1.0E-07	157.8	34.4	32.9	22.3
509	7.5E-08	1.7E-09	7.6E-09	7.0E-08	100.8	18.3	18.1	8.6
510	3.9E-08	2.5E-09	1.2E-08	1.3E-07	268.5	87.0	78.3	39.6
511	3.5E-08	2.3E-09	1.1E-08	1.2E-07	264.9	86.7	77.0	37.5
512	3.6E-08	2.4E-09	1.1E-08	1.2E-07	236.4	83.2	75.2	37.3
513	1.0E-07	1.6E-09	7.6E-09	9.2E-08	164.9	64.1	56.3	28.6
514	3.1E-08	3.7E-10	1.7E-09	1.9E-08	110.0	35.2	26.1	7.9
515	3.4E-08	2.3E-10	1.1E-09	1.1E-08	73.1	15.5	12.4	4.3
516	2.6E-08	-5.0E-11	-2.0E-10	-1.0E-09	33.2	-2.2	-1.7	-0.2
517	1.0E-07	1.6E-09	7.7E-09	9.3E-08	166.4	65.2	57.5	29.0
518	1.2E-07	2.0E-09	9.5E-09	1.1E-07	167.2	65.7	59.7	32.6
519	9.9E-08	1.5E-09	7.2E-09	8.2E-08	102.3	37.0	34.3	20.9
520	3.4E-08	2.3E-10	1.1E-09	1.1E-08	73.6	15.5	12.5	4.3
521	3.4E-08	2.0E-10	9.4E-10	1.0E-08	69.4	12.9	10.7	3.9

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
522	6.5E-08	1.3E-09	6.0E-09	7.3E-08	120.4	52.9	46.2	23.1
523	3.3E-08	2.2E-10	1.1E-09	1.1E-08	73.4	14.8	12.6	4.3
524	2.4E-08	2.4E-10	1.1E-09	1.2E-08	58.3	16.3	12.9	4.8
525	2.5E-08	6.0E-11	2.0E-10	3.0E-09	36.7	3.0	1.9	0.6
526	1.2E-07	1.3E-09	6.2E-09	6.6E-08	96.6	24.6	23.3	15.4
527	1.1E-07	1.4E-09	6.4E-09	6.7E-08	99.1	25.3	24.1	15.6
528	9.0E-08	2.3E-09	1.1E-08	1.3E-07	214.3	82.7	74.0	38.5
529	9.5E-08	1.6E-09	7.4E-09	7.7E-08	77.9	24.4	23.4	16.1
530	6.9E-08	1.8E-09	8.8E-09	1.1E-07	215.6	83.3	72.1	34.5
531	6.4E-08	1.7E-09	7.9E-09	8.8E-08	132.0	47.7	43.9	24.4
532	1.1E-07	1.4E-09	6.6E-09	6.8E-08	99.1	24.7	23.7	15.5
533	1.1E-07	9.1E-10	4.2E-09	4.2E-08	65.2	12.8	12.5	8.8
534	1.1E-07	1.6E-09	7.4E-09	7.7E-08	110.9	29.2	27.8	17.9
535	5.8E-08	2.0E-09	9.7E-09	1.2E-07	162.4	68.7	61.4	33.6
536	6.0E-08	1.9E-09	8.9E-09	1.1E-07	232.0	89.5	76.1	36.0
537	6.7E-08	2.1E-09	9.9E-09	1.2E-07	234.9	89.6	78.6	38.1
538	7.5E-08	2.3E-09	1.1E-08	1.3E-07	239.7	90.5	80.3	40.3
539	5.6E-08	1.7E-09	8.1E-09	9.1E-08	140.3	51.0	46.6	25.7
540	1.1E-07	1.9E-09	8.8E-09	9.0E-08	118.0	31.3	30.2	19.8
541	8.7E-08	1.9E-09	8.6E-09	8.9E-08	101.9	29.5	28.4	19.1
542	1.0E-07	1.1E-09	5.0E-09	4.8E-08	65.4	11.2	11.0	5.7
543	5.9E-08	1.9E-09	8.9E-09	1.1E-07	235.6	89.4	76.7	36.1
544	1.0E-07	1.7E-09	8.0E-09	8.3E-08	118.8	31.9	30.2	19.4
545	1.1E-07	1.9E-09	8.9E-09	9.3E-08	119.9	32.0	30.6	20.5
546	6.2E-08	2.0E-09	9.2E-09	1.0E-07	132.4	50.5	46.7	27.2
547	9.8E-08	1.8E-09	8.2E-09	8.5E-08	121.8	32.9	31.1	19.9
548	5.6E-08	2.0E-09	9.3E-09	1.0E-07	137.5	52.5	48.4	27.9
549	4.9E-08	1.8E-09	8.4E-09	9.4E-08	139.2	53.0	48.3	26.6
550	4.3E-08	1.6E-09	7.4E-09	8.3E-08	151.4	54.3	48.7	25.2
551	9.2E-08	1.9E-09	8.9E-09	9.1E-08	132.0	35.9	34.1	21.4
552	8.1E-08	8.0E-10	3.6E-09	3.5E-08	64.3	8.8	8.6	4.4
553	4.2E-08	1.8E-09	8.6E-09	1.0E-07	266.2	101.1	83.5	36.6
554	8.0E-08	2.0E-09	8.9E-09	8.9E-08	100.8	24.9	24.1	17.4

Pipeline	Failure rate difference (m)				Failure rate difference (%)			
	Rupture	Large hole	Small hole	Pinhole	Rupture	Large hole	Small hole	Pinhole
555	4.2E-08	1.8E-09	8.6E-09	1.0E-07	267.3	100.6	83.5	36.6
556	8.3E-08	2.1E-09	9.7E-09	1.0E-07	146.5	39.9	37.9	23.9
557	7.6E-08	2.2E-09	1.0E-08	1.1E-07	159.5	43.8	41.6	25.9
558	5.0E-08	1.8E-09	8.4E-09	8.6E-08	116.8	36.6	34.6	21.2
559	8.8E-08	1.3E-09	5.8E-09	5.6E-08	80.0	14.7	14.5	7.0
560	9.0E-08	9.3E-10	4.1E-09	3.9E-08	70.3	9.7	9.3	4.7
561	1.0E-07	1.0E-09	4.7E-09	4.4E-08	70.9	9.4	9.7	5.1
562	8.9E-08	5.0E-10	2.4E-09	2.4E-08	59.7	4.7	5.0	2.8
563	1.2E-07	7.0E-10	3.3E-09	3.2E-08	61.2	4.9	5.2	3.3
564	7.6E-08	2.3E-09	1.0E-08	1.1E-07	161.1	44.1	41.6	25.9
565	9.4E-08	1.9E-09	8.7E-09	8.6E-08	99.6	23.5	22.8	16.6
566	4.0E-08	2.2E-09	1.0E-08	1.1E-07	250.9	84.0	74.5	36.4
567	6.4E-08	2.4E-09	1.1E-08	1.2E-07	157.4	47.3	44.8	27.8
568	7.1E-08	2.7E-09	1.2E-08	1.3E-07	158.4	47.4	45.1	29.3
569	7.8E-08	3.0E-09	1.4E-08	1.4E-07	159.2	47.5	45.4	30.4
570	9.8E-08	2.0E-09	9.1E-09	8.6E-08	98.0	18.9	18.6	9.8
571	3.8E-08	2.2E-09	1.1E-08	1.2E-07	229.1	83.1	74.5	37.1
572	8.1E-09	1.1E-09	4.9E-09	5.6E-08	145.9	62.1	51.7	21.0
573	1.1E-07	1.6E-09	7.7E-09	9.1E-08	123.9	50.0	45.6	13.9
574	3.0E-08	8.0E-11	4.0E-10	4.0E-09	44.5	4.2	3.9	0.5
575	1.1E-07	1.5E-09	7.0E-09	7.9E-08	99.1	36.7	34.3	11.5
576	3.0E-08	8.0E-11	4.0E-10	5.0E-09	44.8	4.2	3.9	0.6
577	1.1E-07	7.1E-10	3.3E-09	3.0E-08	57.9	9.5	9.3	2.8
578	1.0E-07	2.4E-09	1.1E-08	1.3E-07	136.1	50.5	47.3	17.6
579	3.7E-08	1.6E-09	7.8E-09	1.0E-07	246.0	104.5	85.2	17.4
580	4.5E-08	2.5E-09	1.2E-08	1.4E-07	247.5	75.1	69.0	20.7
581	3.7E-08	2.1E-09	9.8E-09	1.1E-07	241.8	74.5	67.1	17.7
582	4.1E-08	2.3E-09	1.1E-08	1.2E-07	245.5	74.6	67.5	19.0
583	2.1E-08	1.5E-09	7.2E-09	8.1E-08	162.3	54.4	48.6	13.0
584	1.3E-07	3.4E-09	1.6E-08	1.8E-07	138.9	45.3	43.9	21.6

16 Appendix 6 LUP Zones

16.1 Methane

16.1.1 PIPIN V3.04

Table 23 shows the Land-Use Planning (LUP) zones for the 584 pipeline test set, using the failure rates from PIPIN V3.04.

Table 23 LUP zones using failure rates calculated using PIPIN V3.04

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
1	118	118	375
2	118	118	380
3	118	125	380
4	118	210	385
5	114	114	365
6	114	114	365
7	114	250	375
8	96	140	310
9	3	3	180
10	100	245	345
11	96	185	335
12	93	95	320
13	93	93	320
14	3	3	180
15	3	3	175
16	3	3	175
17	88	260	305
18	82	82	265
19	82	180	285
20	82	195	285
21	82	205	285
22	82	140	280
23	78	78	255
24	78	78	255

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
25	78	78	255
26	78	78	255
27	78	78	260
28	78	120	270
29	78	120	270
30	78	160	275
31	78	160	275
32	78	160	275
33	78	160	275
34	68	68	210
35	62	62	210
36	57	57	190
37	57	57	190
38	3	3	160
39	50	140	195
40	3	3	130
41	65	65	230
42	65	65	230
43	65	175	240
44	65	65	235
45	63	63	205
46	63	63	220
47	63	63	220
48	63	63	220
49	63	140	230
50	63	155	235
51	63	165	235
52	63	63	225
53	3	3	120
54	3	3	110
55	47	47	145
56	47	47	155
57	3	3	105
58	3	3	105

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
59	3	3	105
60	3	3	135
61	3	3	145
62	3	3	145
63	46	46	150
64	46	46	150
65	3	3	115
66	3	3	85
67	3	3	120
68	3	3	125
69	3	3	120
70	3	3	115
71	8	8	140
72	7	7	115
73	15	15	125
74	7	7	7
75	52	52	180
76	52	180	210
77	50	50	150
78	50	50	170
79	50	50	170
80	50	50	170
81	50	50	170
82	50	165	200
83	50	170	200
84	49	165	195
85	49	165	195
86	41	90	165
87	3	3	100
88	3	3	100
89	40	40	120
90	40	75	160
91	9	9	135
92	3	3	100

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
93	37	37	110
94	9	9	125
95	9	9	130
96	9	9	130
97	37	37	145
98	9	9	120
99	36	36	135
100	9	9	120
101	9	9	110
102	3	3	24
103	3	3	30
104	3	3	60
105	3	3	65
106	3	3	95
107	3	3	95
108	9	9	105
109	9	9	115
110	9	9	120
111	35	35	135
112	3	3	20
113	3	3	95
114	3	3	95
115	3	3	95
116	3	3	95
117	3	3	110
118	8	8	100
119	35	35	125
120	35	35	135
121	3	3	90
122	8	8	100
123	8	8	105
124	3	3	85
125	8	8	95
126	34	34	120

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
127	34	34	115
128	3	3	75
129	3	3	80
130	16	85	140
131	33	110	145
132	8	8	125
133	8	8	85
134	16	80	135
135	8	8	65
136	3	3	3
137	16	47	120
138	16	65	125
139	16	16	115
140	15	43	115
141	15	15	105
142	3	3	3
143	3	3	3
144	3	3	3
145	15	15	70
146	3	3	3
147	3	3	3
148	3	3	3
149	7	7	7
150	7	7	7
151	50	50	155
152	8	8	95
153	8	8	95
154	17	65	115
155	8	8	70
156	15	15	55
157	15	15	43
158	45	45	125
159	3	3	40
160	40	40	105

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
161	40	40	105
162	40	40	105
163	40	40	130
164	40	70	145
165	40	85	145
166	40	95	145
167	39	39	105
168	39	39	105
169	39	65	145
170	39	80	145
171	39	90	145
172	39	60	140
173	33	33	95
174	9	10	110
175	9	9	105
176	9	10	105
177	18	55	110
178	30	30	105
179	9	9	100
180	9	9	55
181	17	39	105
182	17	60	110
183	9	9	40
184	9	9	50
185	9	9	95
186	9	9	90
187	17	42	105
188	17	50	105
189	8	8	95
190	8	8	90
191	17	44	100
192	8	8	41
193	17	17	95
194	17	17	95

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
195	8	8	85
196	17	17	90
197	8	8	65
198	8	8	80
199	16	33	95
200	16	16	90
201	16	16	95
202	16	16	95
203	27	55	100
204	16	24	95
205	8	8	65
206	16	16	90
207	16	16	85
208	16	16	85
209	16	95	100
210	16	90	105
211	16	16	60
212	16	16	60
213	16	35	85
214	16	16	60
215	16	55	90
216	15	15	80
217	15	60	85
218	15	15	50
219	15	15	55
220	15	55	85
221	15	15	42
222	15	15	31
223	15	15	48
224	15	70	75
225	15	75	75
226	7	7	7
227	15	15	15
228	7	7	7

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
229	7	7	7
230	7	7	7
231	3	3	3
232	9	9	70
233	9	9	70
234	16	60	85
235	16	16	75
236	16	16	65
237	16	16	55
238	16	16	55
239	16	65	85
240	16	27	75
241	3	3	3
242	16	46	75
243	16	50	75
244	16	75	80
245	15	15	43
246	15	15	38
247	15	35	70
248	7	7	7
249	15	15	55
250	15	38	65
251	40	90	115
252	17	55	75
253	16	50	70
254	16	49	70
255	16	29	70
256	15	60	65
257	14	14	30
258	33	95	105
259	32	55	100
260	32	90	100
261	32	85	100
262	32	90	100

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
263	32	80	100
264	32	90	100
265	32	80	100
266	32	80	100
267	26	44	80
268	18	65	80
269	18	60	75
270	24	41	75
271	18	70	75
272	17	41	75
273	17	65	75
274	3	3	3
275	17	37	70
276	17	65	75
277	17	17	49
278	17	65	75
279	17	65	75
280	3	3	3
281	17	17	65
282	17	65	75
283	3	3	3
284	17	45	70
285	17	60	70
286	17	65	70
287	17	60	70
288	17	65	70
289	17	65	70
290	17	17	65
291	17	60	70
292	17	70	70
293	17	65	70
294	17	17	47
295	17	60	70
296	17	55	70

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
297	17	17	45
298	17	17	41
299	17	55	70
300	17	60	70
301	16	16	55
302	16	41	65
303	16	17	60
304	16	34	65
305	16	48	65
306	16	55	65
307	16	65	65
308	16	60	65
309	3	3	3
310	16	16	35
311	16	16	55
312	16	16	55
313	16	16	60
314	16	16	55
315	16	16	60
316	16	47	65
317	16	65	80
318	16	43	65
319	16	38	55
320	16	38	55
321	20	40	60
322	16	32	55
323	16	35	55
324	3	3	3
325	16	33	55
326	16	55	60
327	16	55	60
328	15	29	55
329	3	3	3
330	15	24	50

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
331	15	33	55
332	15	47	55
333	15	49	55
334	15	44	55
335	15	41	55
336	15	55	55
337	15	15	15
338	15	15	30
339	15	23	50
340	15	46	55
341	19	41	55
342	15	15	44
343	15	40	50
344	15	38	50
345	15	15	15
346	15	15	15
347	15	15	17
348	15	15	15
349	15	15	35
350	15	15	29
351	15	15	22
352	15	22	46
353	15	15	44
354	15	15	40
355	15	15	40
356	15	37	48
357	15	35	47
358	15	35	47
359	15	36	48
360	15	37	48
361	15	25	46
362	15	18	45
363	15	48	50
364	15	15	29

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
365	15	37	48
366	15	15	24
367	15	15	35
368	15	15	36
369	15	15	33
370	15	15	34
371	14	14	14
372	14	14	36
373	14	14	14
374	14	14	38
375	14	14	38
376	14	23	39
377	14	14	37
378	14	14	28
379	14	14	14
380	14	14	14
381	13	13	13
382	33	75	85
383	32	70	85
384	32	70	85
385	32	70	85
386	32	70	85
387	3	3	3
388	18	60	65
389	3	3	3
390	3	3	3
391	17	55	60
392	17	50	60
393	17	32	55
394	17	45	55
395	17	50	55
396	17	55	55
397	17	17	50
398	17	50	55

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
399	17	50	55
400	16	46	50
401	16	16	45
402	15	33	43
403	15	15	34
404	15	15	34
405	15	34	43
406	15	17	36
407	15	21	36
408	15	15	35
409	15	15	33
410	15	15	15
411	15	15	31
412	15	25	37
413	15	30	38
414	15	15	34
415	15	15	33
416	15	15	33
417	15	15	34
418	15	15	35
419	15	15	34
420	15	15	30
421	15	15	21
422	14	14	25
423	14	14	29
424	33	44	65
425	32	43	60
426	32	41	60
427	32	50	65
428	32	32	42
429	32	42	60
430	32	43	60
431	3	3	5
432	31	41	60

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
433	18	47	50
434	18	47	50
435	18	46	50
436	18	43	48
437	18	40	45
438	18	38	45
439	18	38	45
440	17	38	45
441	17	34	43
442	17	37	43
443	17	34	43
444	17	33	43
445	17	30	42
446	17	33	43
447	17	17	38
448	17	33	41
449	17	32	41
450	17	33	41
451	17	27	40
452	17	32	41
453	17	32	41
454	17	17	26
455	17	30	41
456	17	32	38
457	16	18	36
458	16	30	38
459	16	27	37
460	16	16	20
461	16	16	31
462	16	27	37
463	16	25	37
464	16	31	38
465	16	16	16
466	16	16	32

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
467	16	25	34
468	16	16	32
469	16	16	32
470	15	15	28
471	15	34	36
472	15	15	28
473	15	22	30
474	15	25	31
475	15	29	31
476	15	28	31
477	15	28	31
478	15	15	15
479	15	15	25
480	15	15	19
481	15	15	28
482	15	15	29
483	15	15	28
484	15	23	30
485	15	28	31
486	15	15	26
487	15	27	29
488	15	15	25
489	15	15	24
490	15	15	25
491	15	15	24
492	15	15	24
493	15	15	25
494	15	15	22
495	15	15	21
496	15	15	22
497	15	21	27
498	15	15	26
499	15	25	27
500	15	26	27

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
501	15	15	23
502	15	15	22
503	15	26	27
504	15	15	18
505	15	15	16
506	15	23	25
507	15	15	18
508	14	14	23
509	14	19	24
510	14	14	14
511	14	14	14
512	14	14	14
513	21	33	43
514	20	20	40
515	20	31	43
516	20	40	45
517	21	33	43
518	21	37	43
519	21	40	43
520	19	31	43
521	19	32	43
522	21	32	43
523	19	31	43
524	19	29	42
525	19	35	43
526	18	32	34
527	18	31	34
528	18	18	30
529	18	28	31
530	18	18	27
531	18	20	30
532	18	28	31
533	18	30	31
534	17	26	29

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
535	17	17	25
536	17	17	24
537	17	17	24
538	17	17	25
539	17	17	25
540	17	26	29
541	17	25	29
542	17	28	29
543	17	17	24
544	17	24	27
545	17	24	27
546	17	17	26
547	17	23	27
548	16	16	24
549	16	16	24
550	16	16	23
551	16	20	25
552	16	24	25
553	16	16	16
554	16	20	24
555	16	16	16
556	16	16	23
557	15	15	21
558	15	15	21
559	15	20	23
560	15	22	23
561	15	22	23
562	15	22	23
563	15	22	23
564	15	15	21
565	15	20	23
566	15	15	15
567	15	15	19
568	15	15	19

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.04		
	Inner	Middle	Outer
569	15	15	19
570	15	18	20
571	15	15	15
572	14	14	15
573	21	21	24
574	20	20	24
575	21	22	24
576	19	19	23
577	18	19	21
578	18	18	18
579	16	16	16
580	15	15	15
581	15	15	15
582	15	15	15
583	15	15	15
584	17	17	17

16.1.2 PIPIN V3.1

Table 24 shows the Land-Use Planning (LUP) zones for the 584 pipeline test set, using the failure rates from PIPIN V3.1.

Table 24 LUP zones using failure rates calculated using PIPIN V3.1

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
1	118	118	375
2	118	118	380
3	118	118	380
4	118	150	385
5	114	114	365
6	114	114	365
7	114	200	370
8	96	96	305
9	3	3	180
10	100	215	345

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
11	96	135	335
12	93	93	320
13	93	93	315
14	3	3	180
15	3	3	170
16	3	3	155
17	88	240	305
18	82	82	265
19	82	125	280
20	82	145	285
21	82	165	285
22	82	82	280
23	78	78	255
24	78	78	250
25	78	78	250
26	78	78	250
27	78	78	260
28	78	78	270
29	78	78	270
30	78	80	270
31	78	80	270
32	78	80	270
33	78	80	270
34	68	68	210
35	62	62	205
36	57	57	185
37	57	57	185
38	3	3	145
39	50	95	185
40	3	3	120
41	65	65	230
42	65	65	230
43	65	165	240
44	65	65	230

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
45	63	63	200
46	63	63	220
47	63	63	220
48	63	63	220
49	63	125	230
50	63	140	230
51	63	155	235
52	63	63	225
53	3	3	115
54	3	3	110
55	47	47	145
56	47	47	150
57	3	3	100
58	3	3	105
59	3	3	105
60	3	3	130
61	3	3	135
62	3	3	135
63	46	46	150
64	46	46	150
65	3	3	115
66	3	3	85
67	3	3	120
68	3	3	120
69	3	3	115
70	3	3	115
71	8	8	135
72	7	7	110
73	15	15	120
74	7	7	7
75	52	52	180
76	52	175	210
77	50	50	145
78	50	50	170

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
79	50	50	170
80	50	50	170
81	50	50	170
82	50	165	195
83	50	170	200
84	49	160	195
85	49	160	195
86	41	75	165
87	3	3	95
88	3	3	100
89	40	40	115
90	40	55	160
91	9	9	130
92	3	3	100
93	37	37	110
94	9	9	120
95	9	9	125
96	9	9	125
97	37	37	140
98	9	9	110
99	36	36	130
100	9	9	110
101	9	9	100
102	3	3	19
103	3	3	26
104	3	3	55
105	3	3	60
106	3	3	90
107	3	3	95
108	9	9	95
109	9	9	105
110	9	9	115
111	35	35	130
112	3	3	12

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
113	3	3	90
114	3	3	95
115	3	3	95
116	3	3	95
117	3	3	100
118	8	8	95
119	35	35	120
120	35	35	130
121	3	3	90
122	8	8	95
123	8	8	95
124	3	3	80
125	8	8	90
126	34	34	115
127	34	34	110
128	3	3	70
129	3	3	75
130	16	80	140
131	33	110	145
132	8	8	120
133	8	8	80
134	16	75	135
135	8	8	60
136	3	3	3
137	16	20	120
138	16	55	120
139	16	16	115
140	15	15	115
141	15	15	105
142	3	3	3
143	3	3	3
144	3	3	3
145	15	15	70
146	3	3	3

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
147	3	3	3
148	3	3	3
149	7	7	7
150	7	7	7
151	50	50	150
152	8	8	85
153	8	8	85
154	17	60	115
155	8	8	70
156	15	15	55
157	15	15	37
158	45	45	125
159	3	3	34
160	40	40	100
161	40	40	100
162	40	40	105
163	40	40	125
164	40	55	140
165	40	70	145
166	40	85	145
167	39	39	100
168	39	39	105
169	39	49	140
170	39	70	145
171	39	80	145
172	39	43	140
173	33	33	95
174	9	9	110
175	9	9	100
176	9	9	105
177	18	46	110
178	30	30	100
179	9	9	95
180	9	9	50

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
181	17	18	105
182	17	50	105
183	9	9	30
184	9	9	43
185	9	9	90
186	9	9	85
187	17	24	105
188	17	41	105
189	8	8	90
190	8	8	85
191	17	27	100
192	8	8	32
193	17	17	95
194	17	17	95
195	8	8	80
196	17	17	85
197	8	8	65
198	8	8	70
199	16	16	95
200	16	16	85
201	16	16	90
202	16	16	90
203	27	50	95
204	16	16	90
205	8	8	65
206	16	16	85
207	16	16	80
208	16	16	85
209	16	95	100
210	16	90	95
211	16	16	60
212	16	16	60
213	16	21	85
214	16	16	55

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
215	16	55	90
216	15	15	75
217	15	55	85
218	15	15	48
219	15	15	50
220	15	50	80
221	15	15	36
222	15	15	22
223	15	15	45
224	15	70	75
225	15	70	75
226	7	7	7
227	15	15	15
228	7	7	7
229	7	7	7
230	7	7	7
231	3	3	3
232	9	9	65
233	9	9	65
234	16	55	85
235	16	16	75
236	16	16	60
237	16	16	55
238	16	16	55
239	16	60	85
240	16	16	70
241	3	3	3
242	16	43	75
243	16	50	75
244	16	75	80
245	15	15	39
246	15	15	33
247	15	26	70
248	7	7	7

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
249	15	15	55
250	15	34	65
251	40	85	115
252	17	50	75
253	16	49	70
254	16	47	70
255	16	16	70
256	15	60	65
257	14	14	29
258	33	90	105
259	32	50	95
260	32	85	100
261	32	80	100
262	32	85	100
263	32	80	100
264	32	90	100
265	32	75	100
266	32	80	100
267	26	39	80
268	18	65	80
269	18	55	75
270	24	36	75
271	18	70	75
272	17	36	70
273	17	65	75
274	3	3	3
275	17	29	70
276	17	65	75
277	17	17	49
278	17	65	75
279	17	65	75
280	3	3	3
281	17	17	60
282	17	65	75

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
283	3	3	3
284	17	41	70
285	17	60	70
286	17	60	70
287	17	60	70
288	17	60	70
289	17	60	70
290	17	17	60
291	17	60	70
292	17	70	70
293	17	65	70
294	17	17	45
295	17	60	70
296	17	50	70
297	17	17	43
298	17	17	38
299	17	55	70
300	17	60	70
301	16	16	55
302	16	37	65
303	16	16	60
304	16	29	60
305	16	46	65
306	16	55	65
307	16	65	65
308	16	60	65
309	3	3	3
310	16	16	30
311	16	16	55
312	16	16	50
313	16	16	55
314	16	16	55
315	16	16	55
316	16	46	65

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
317	16	65	80
318	16	42	60
319	16	35	55
320	16	35	55
321	20	39	55
322	16	27	55
323	16	32	55
324	3	3	3
325	16	30	55
326	16	50	60
327	16	55	60
328	15	23	55
329	3	3	3
330	15	15	50
331	15	30	50
332	15	45	55
333	15	47	55
334	15	42	55
335	15	40	55
336	15	55	55
337	15	15	15
338	15	15	27
339	15	15	50
340	15	45	55
341	19	41	55
342	15	15	42
343	15	39	50
344	15	38	50
345	15	15	15
346	15	15	15
347	15	15	15
348	15	15	15
349	15	15	34
350	15	15	25

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
351	15	15	15
352	15	15	45
353	15	15	42
354	15	15	38
355	15	15	38
356	15	36	48
357	15	33	47
358	15	33	47
359	15	35	47
360	15	36	48
361	15	21	45
362	15	15	44
363	15	48	50
364	15	15	25
365	15	36	48
366	15	15	19
367	15	15	34
368	15	15	35
369	15	15	32
370	15	15	33
371	14	14	14
372	14	14	35
373	14	14	14
374	14	14	36
375	14	14	37
376	14	19	39
377	14	14	36
378	14	14	27
379	14	14	14
380	14	14	14
381	13	13	13
382	33	75	85
383	32	70	85
384	32	70	85

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
385	32	65	85
386	32	70	85
387	3	3	3
388	18	60	65
389	3	3	3
390	3	3	3
391	17	55	60
392	17	50	60
393	17	28	55
394	17	42	55
395	17	50	55
396	17	50	55
397	17	17	50
398	17	50	55
399	17	50	55
400	16	45	50
401	16	16	44
402	15	32	43
403	15	15	34
404	15	15	34
405	15	33	43
406	15	15	35
407	15	18	36
408	15	15	34
409	15	15	32
410	15	15	15
411	15	15	31
412	15	22	37
413	15	29	38
414	15	15	33
415	15	15	32
416	15	15	32
417	15	15	33
418	15	15	34

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
419	15	15	33
420	15	15	30
421	15	15	18
422	14	14	23
423	14	14	29
424	33	44	65
425	32	42	60
426	32	39	60
427	32	50	65
428	32	32	41
429	32	42	60
430	32	43	60
431	3	3	5
432	31	40	60
433	18	46	50
434	18	46	50
435	18	46	50
436	18	42	48
437	18	39	45
438	18	37	45
439	18	37	45
440	17	36	45
441	17	34	43
442	17	36	43
443	17	34	43
444	17	33	43
445	17	28	42
446	17	33	43
447	17	17	38
448	17	32	41
449	17	31	41
450	17	33	41
451	17	24	40
452	17	31	41

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
453	17	32	41
454	17	17	24
455	17	28	40
456	17	31	38
457	16	16	36
458	16	30	38
459	16	26	37
460	16	16	17
461	16	16	31
462	16	26	37
463	16	23	37
464	16	31	38
465	16	16	16
466	16	16	32
467	16	24	33
468	16	16	31
469	16	16	31
470	15	15	28
471	15	33	35
472	15	15	28
473	15	20	30
474	15	25	31
475	15	29	31
476	15	28	31
477	15	28	31
478	15	15	15
479	15	15	24
480	15	15	16
481	15	15	28
482	15	15	28
483	15	15	28
484	15	21	30
485	15	28	31
486	15	15	26

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
487	15	27	29
488	15	15	25
489	15	15	23
490	15	15	25
491	15	15	23
492	15	15	24
493	15	15	25
494	15	15	22
495	15	15	20
496	15	15	21
497	15	20	26
498	15	15	26
499	15	25	27
500	15	25	27
501	15	15	22
502	15	15	21
503	15	26	27
504	15	15	17
505	15	15	15
506	15	22	25
507	15	15	16
508	14	14	23
509	14	19	24
510	14	14	14
511	14	14	14
512	14	14	14
513	21	32	43
514	20	20	39
515	20	30	42
516	20	40	45
517	21	32	43
518	21	36	43
519	21	40	43
520	19	30	42

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
521	19	31	43
522	21	32	43
523	19	30	42
524	19	28	42
525	19	34	43
526	18	31	34
527	18	31	34
528	18	18	29
529	18	28	31
530	18	18	27
531	18	18	30
532	18	27	31
533	18	30	31
534	17	26	29
535	17	17	25
536	17	17	23
537	17	17	24
538	17	17	24
539	17	17	25
540	17	26	29
541	17	25	29
542	17	28	29
543	17	17	23
544	17	23	27
545	17	24	27
546	17	17	25
547	17	23	27
548	16	16	24
549	16	16	23
550	16	16	22
551	16	19	25
552	16	24	25
553	16	16	16
554	16	19	24

Pipeline	Methane MISHAP LUP zones (m) from PIPIN V3.1		
	Inner	Middle	Outer
555	16	16	16
556	16	16	23
557	15	15	21
558	15	15	21
559	15	20	23
560	15	21	23
561	15	22	23
562	15	22	23
563	15	22	23
564	15	15	21
565	15	19	23
566	15	15	15
567	15	15	18
568	15	15	19
569	15	15	19
570	15	17	20
571	15	15	15
572	14	14	15
573	21	21	24
574	20	20	23
575	21	21	24
576	19	19	23
577	18	19	21
578	18	18	18
579	16	16	16
580	15	15	15
581	15	15	15
582	15	15	15
583	15	15	15
584	17	17	17

16.1.3 LUP zone comparison

The LUP zones detailed in Sections 16.116.1.1 and 16.1.2 have been compared. The results of the comparison are shown in Table 25 where the differences are calculated as new – old and the percentage differences are (new – old) / old. “New” represents the results from MISHAP using the failure rates calculated by PIPIN V3.1 and “old” refers to the LUP zones from MISHAP using the failure rates calculated by PIPIN V3.04.

Table 25 Comparison of LUP zones for the methane pipelines

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
1	0	0	0	0.0%	0.0%	0.0%
2	0	0	0	0.0%	0.0%	0.0%
3	0	-7	0	0.0%	-5.6%	0.0%
4	0	-60	0	0.0%	-28.6%	0.0%
5	0	0	0	0.0%	0.0%	0.0%
6	0	0	0	0.0%	0.0%	0.0%
7	0	-50	-5	0.0%	-20.0%	-1.3%
8	0	-44	-5	0.0%	-31.4%	-1.6%
9	0	0	0	0.0%	0.0%	0.0%
10	0	-30	0	0.0%	-12.2%	0.0%
11	0	-50	0	0.0%	-27.0%	0.0%
12	0	-2	0	0.0%	-2.1%	0.0%
13	0	0	-5	0.0%	0.0%	-1.6%
14	0	0	0	0.0%	0.0%	0.0%
15	0	0	-5	0.0%	0.0%	-2.9%
16	0	0	-20	0.0%	0.0%	-11.4%
17	0	-20	0	0.0%	-7.7%	0.0%
18	0	0	0	0.0%	0.0%	0.0%
19	0	-55	-5	0.0%	-30.6%	-1.8%
20	0	-50	0	0.0%	-25.6%	0.0%
21	0	-40	0	0.0%	-19.5%	0.0%
22	0	-58	0	0.0%	-41.4%	0.0%
23	0	0	0	0.0%	0.0%	0.0%
24	0	0	-5	0.0%	0.0%	-2.0%
25	0	0	-5	0.0%	0.0%	-2.0%
26	0	0	-5	0.0%	0.0%	-2.0%
27	0	0	0	0.0%	0.0%	0.0%
28	0	-42	0	0.0%	-35.0%	0.0%
29	0	-42	0	0.0%	-35.0%	0.0%
30	0	-80	-5	0.0%	-50.0%	-1.8%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
31	0	-80	-5	0.0%	-50.0%	-1.8%
32	0	-80	-5	0.0%	-50.0%	-1.8%
33	0	-80	-5	0.0%	-50.0%	-1.8%
34	0	0	0	0.0%	0.0%	0.0%
35	0	0	-5	0.0%	0.0%	-2.4%
36	0	0	-5	0.0%	0.0%	-2.6%
37	0	0	-5	0.0%	0.0%	-2.6%
38	0	0	-15	0.0%	0.0%	-9.4%
39	0	-45	-10	0.0%	-32.1%	-5.1%
40	0	0	-10	0.0%	0.0%	-7.7%
41	0	0	0	0.0%	0.0%	0.0%
42	0	0	0	0.0%	0.0%	0.0%
43	0	-10	0	0.0%	-5.7%	0.0%
44	0	0	-5	0.0%	0.0%	-2.1%
45	0	0	-5	0.0%	0.0%	-2.4%
46	0	0	0	0.0%	0.0%	0.0%
47	0	0	0	0.0%	0.0%	0.0%
48	0	0	0	0.0%	0.0%	0.0%
49	0	-15	0	0.0%	-10.7%	0.0%
50	0	-15	-5	0.0%	-9.7%	-2.1%
51	0	-10	0	0.0%	-6.1%	0.0%
52	0	0	0	0.0%	0.0%	0.0%
53	0	0	-5	0.0%	0.0%	-4.2%
54	0	0	0	0.0%	0.0%	0.0%
55	0	0	0	0.0%	0.0%	0.0%
56	0	0	-5	0.0%	0.0%	-3.2%
57	0	0	-5	0.0%	0.0%	-4.8%
58	0	0	0	0.0%	0.0%	0.0%
59	0	0	0	0.0%	0.0%	0.0%
60	0	0	-5	0.0%	0.0%	-3.7%
61	0	0	-10	0.0%	0.0%	-6.9%
62	0	0	-10	0.0%	0.0%	-6.9%
63	0	0	0	0.0%	0.0%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
64	0	0	0	0.0%	0.0%	0.0%
65	0	0	0	0.0%	0.0%	0.0%
66	0	0	0	0.0%	0.0%	0.0%
67	0	0	0	0.0%	0.0%	0.0%
68	0	0	-5	0.0%	0.0%	-4.0%
69	0	0	-5	0.0%	0.0%	-4.2%
70	0	0	0	0.0%	0.0%	0.0%
71	0	0	-5	0.0%	0.0%	-3.6%
72	0	0	-5	0.0%	0.0%	-4.3%
73	0	0	-5	0.0%	0.0%	-4.0%
74	0	0	0	0.0%	0.0%	0.0%
75	0	0	0	0.0%	0.0%	0.0%
76	0	-5	0	0.0%	-2.8%	0.0%
77	0	0	-5	0.0%	0.0%	-3.3%
78	0	0	0	0.0%	0.0%	0.0%
79	0	0	0	0.0%	0.0%	0.0%
80	0	0	0	0.0%	0.0%	0.0%
81	0	0	0	0.0%	0.0%	0.0%
82	0	0	-5	0.0%	0.0%	-2.5%
83	0	0	0	0.0%	0.0%	0.0%
84	0	-5	0	0.0%	-3.0%	0.0%
85	0	-5	0	0.0%	-3.0%	0.0%
86	0	-15	0	0.0%	-16.7%	0.0%
87	0	0	-5	0.0%	0.0%	-5.0%
88	0	0	0	0.0%	0.0%	0.0%
89	0	0	-5	0.0%	0.0%	-4.2%
90	0	-20	0	0.0%	-26.7%	0.0%
91	0	0	-5	0.0%	0.0%	-3.7%
92	0	0	0	0.0%	0.0%	0.0%
93	0	0	0	0.0%	0.0%	0.0%
94	0	0	-5	0.0%	0.0%	-4.0%
95	0	0	-5	0.0%	0.0%	-3.8%
96	0	0	-5	0.0%	0.0%	-3.8%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
97	0	0	-5	0.0%	0.0%	-3.4%
98	0	0	-10	0.0%	0.0%	-8.3%
99	0	0	-5	0.0%	0.0%	-3.7%
100	0	0	-10	0.0%	0.0%	-8.3%
101	0	0	-10	0.0%	0.0%	-9.1%
102	0	0	-5	0.0%	0.0%	-20.8%
103	0	0	-4	0.0%	0.0%	-13.3%
104	0	0	-5	0.0%	0.0%	-8.3%
105	0	0	-5	0.0%	0.0%	-7.7%
106	0	0	-5	0.0%	0.0%	-5.3%
107	0	0	0	0.0%	0.0%	0.0%
108	0	0	-10	0.0%	0.0%	-9.5%
109	0	0	-10	0.0%	0.0%	-8.7%
110	0	0	-5	0.0%	0.0%	-4.2%
111	0	0	-5	0.0%	0.0%	-3.7%
112	0	0	-8	0.0%	0.0%	-40.0%
113	0	0	-5	0.0%	0.0%	-5.3%
114	0	0	0	0.0%	0.0%	0.0%
115	0	0	0	0.0%	0.0%	0.0%
116	0	0	0	0.0%	0.0%	0.0%
117	0	0	-10	0.0%	0.0%	-9.1%
118	0	0	-5	0.0%	0.0%	-5.0%
119	0	0	-5	0.0%	0.0%	-4.0%
120	0	0	-5	0.0%	0.0%	-3.7%
121	0	0	0	0.0%	0.0%	0.0%
122	0	0	-5	0.0%	0.0%	-5.0%
123	0	0	-10	0.0%	0.0%	-9.5%
124	0	0	-5	0.0%	0.0%	-5.9%
125	0	0	-5	0.0%	0.0%	-5.3%
126	0	0	-5	0.0%	0.0%	-4.2%
127	0	0	-5	0.0%	0.0%	-4.3%
128	0	0	-5	0.0%	0.0%	-6.7%
129	0	0	-5	0.0%	0.0%	-6.3%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
130	0	-5	0	0.0%	-5.9%	0.0%
131	0	0	0	0.0%	0.0%	0.0%
132	0	0	-5	0.0%	0.0%	-4.0%
133	0	0	-5	0.0%	0.0%	-5.9%
134	0	-5	0	0.0%	-6.3%	0.0%
135	0	0	-5	0.0%	0.0%	-7.7%
136	0	0	0	0.0%	0.0%	0.0%
137	0	-27	0	0.0%	-57.4%	0.0%
138	0	-10	-5	0.0%	-15.4%	-4.0%
139	0	0	0	0.0%	0.0%	0.0%
140	0	-28	0	0.0%	-65.1%	0.0%
141	0	0	0	0.0%	0.0%	0.0%
142	0	0	0	0.0%	0.0%	0.0%
143	0	0	0	0.0%	0.0%	0.0%
144	0	0	0	0.0%	0.0%	0.0%
145	0	0	0	0.0%	0.0%	0.0%
146	0	0	0	0.0%	0.0%	0.0%
147	0	0	0	0.0%	0.0%	0.0%
148	0	0	0	0.0%	0.0%	0.0%
149	0	0	0	0.0%	0.0%	0.0%
150	0	0	0	0.0%	0.0%	0.0%
151	0	0	-5	0.0%	0.0%	-3.2%
152	0	0	-10	0.0%	0.0%	-10.5%
153	0	0	-10	0.0%	0.0%	-10.5%
154	0	-5	0	0.0%	-7.7%	0.0%
155	0	0	0	0.0%	0.0%	0.0%
156	0	0	0	0.0%	0.0%	0.0%
157	0	0	-6	0.0%	0.0%	-14.0%
158	0	0	0	0.0%	0.0%	0.0%
159	0	0	-6	0.0%	0.0%	-15.0%
160	0	0	-5	0.0%	0.0%	-4.8%
161	0	0	-5	0.0%	0.0%	-4.8%
162	0	0	0	0.0%	0.0%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
163	0	0	-5	0.0%	0.0%	-3.8%
164	0	-15	-5	0.0%	-21.4%	-3.4%
165	0	-15	0	0.0%	-17.6%	0.0%
166	0	-10	0	0.0%	-10.5%	0.0%
167	0	0	-5	0.0%	0.0%	-4.8%
168	0	0	0	0.0%	0.0%	0.0%
169	0	-16	-5	0.0%	-24.6%	-3.4%
170	0	-10	0	0.0%	-12.5%	0.0%
171	0	-10	0	0.0%	-11.1%	0.0%
172	0	-17	0	0.0%	-28.3%	0.0%
173	0	0	0	0.0%	0.0%	0.0%
174	0	-1	0	0.0%	-10.0%	0.0%
175	0	0	-5	0.0%	0.0%	-4.8%
176	0	-1	0	0.0%	-10.0%	0.0%
177	0	-9	0	0.0%	-16.4%	0.0%
178	0	0	-5	0.0%	0.0%	-4.8%
179	0	0	-5	0.0%	0.0%	-5.0%
180	0	0	-5	0.0%	0.0%	-9.1%
181	0	-21	0	0.0%	-53.8%	0.0%
182	0	-10	-5	0.0%	-16.7%	-4.5%
183	0	0	-10	0.0%	0.0%	-25.0%
184	0	0	-7	0.0%	0.0%	-14.0%
185	0	0	-5	0.0%	0.0%	-5.3%
186	0	0	-5	0.0%	0.0%	-5.6%
187	0	-18	0	0.0%	-42.9%	0.0%
188	0	-9	0	0.0%	-18.0%	0.0%
189	0	0	-5	0.0%	0.0%	-5.3%
190	0	0	-5	0.0%	0.0%	-5.6%
191	0	-17	0	0.0%	-38.6%	0.0%
192	0	0	-9	0.0%	0.0%	-22.0%
193	0	0	0	0.0%	0.0%	0.0%
194	0	0	0	0.0%	0.0%	0.0%
195	0	0	-5	0.0%	0.0%	-5.9%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
196	0	0	-5	0.0%	0.0%	-5.6%
197	0	0	0	0.0%	0.0%	0.0%
198	0	0	-10	0.0%	0.0%	-12.5%
199	0	-17	0	0.0%	-51.5%	0.0%
200	0	0	-5	0.0%	0.0%	-5.6%
201	0	0	-5	0.0%	0.0%	-5.3%
202	0	0	-5	0.0%	0.0%	-5.3%
203	0	-5	-5	0.0%	-9.1%	-5.0%
204	0	-8	-5	0.0%	-33.3%	-5.3%
205	0	0	0	0.0%	0.0%	0.0%
206	0	0	-5	0.0%	0.0%	-5.6%
207	0	0	-5	0.0%	0.0%	-5.9%
208	0	0	0	0.0%	0.0%	0.0%
209	0	0	0	0.0%	0.0%	0.0%
210	0	0	-10	0.0%	0.0%	-9.5%
211	0	0	0	0.0%	0.0%	0.0%
212	0	0	0	0.0%	0.0%	0.0%
213	0	-14	0	0.0%	-40.0%	0.0%
214	0	0	-5	0.0%	0.0%	-8.3%
215	0	0	0	0.0%	0.0%	0.0%
216	0	0	-5	0.0%	0.0%	-6.3%
217	0	-5	0	0.0%	-8.3%	0.0%
218	0	0	-2	0.0%	0.0%	-4.0%
219	0	0	-5	0.0%	0.0%	-9.1%
220	0	-5	-5	0.0%	-9.1%	-5.9%
221	0	0	-6	0.0%	0.0%	-14.3%
222	0	0	-9	0.0%	0.0%	-29.0%
223	0	0	-3	0.0%	0.0%	-6.3%
224	0	0	0	0.0%	0.0%	0.0%
225	0	-5	0	0.0%	-6.7%	0.0%
226	0	0	0	0.0%	0.0%	0.0%
227	0	0	0	0.0%	0.0%	0.0%
228	0	0	0	0.0%	0.0%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
229	0	0	0	0.0%	0.0%	0.0%
230	0	0	0	0.0%	0.0%	0.0%
231	0	0	0	0.0%	0.0%	0.0%
232	0	0	-5	0.0%	0.0%	-7.1%
233	0	0	-5	0.0%	0.0%	-7.1%
234	0	-5	0	0.0%	-8.3%	0.0%
235	0	0	0	0.0%	0.0%	0.0%
236	0	0	-5	0.0%	0.0%	-7.7%
237	0	0	0	0.0%	0.0%	0.0%
238	0	0	0	0.0%	0.0%	0.0%
239	0	-5	0	0.0%	-7.7%	0.0%
240	0	-11	-5	0.0%	-40.7%	-6.7%
241	0	0	0	0.0%	0.0%	0.0%
242	0	-3	0	0.0%	-6.5%	0.0%
243	0	0	0	0.0%	0.0%	0.0%
244	0	0	0	0.0%	0.0%	0.0%
245	0	0	-4	0.0%	0.0%	-9.3%
246	0	0	-5	0.0%	0.0%	-13.2%
247	0	-9	0	0.0%	-25.7%	0.0%
248	0	0	0	0.0%	0.0%	0.0%
249	0	0	0	0.0%	0.0%	0.0%
250	0	-4	0	0.0%	-10.5%	0.0%
251	0	-5	0	0.0%	-5.6%	0.0%
252	0	-5	0	0.0%	-9.1%	0.0%
253	0	-1	0	0.0%	-2.0%	0.0%
254	0	-2	0	0.0%	-4.1%	0.0%
255	0	-13	0	0.0%	-44.8%	0.0%
256	0	0	0	0.0%	0.0%	0.0%
257	0	0	-1	0.0%	0.0%	-3.3%
258	0	-5	0	0.0%	-5.3%	0.0%
259	0	-5	-5	0.0%	-9.1%	-5.0%
260	0	-5	0	0.0%	-5.6%	0.0%
261	0	-5	0	0.0%	-5.9%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
262	0	-5	0	0.0%	-5.6%	0.0%
263	0	0	0	0.0%	0.0%	0.0%
264	0	0	0	0.0%	0.0%	0.0%
265	0	-5	0	0.0%	-6.3%	0.0%
266	0	0	0	0.0%	0.0%	0.0%
267	0	-5	0	0.0%	-11.4%	0.0%
268	0	0	0	0.0%	0.0%	0.0%
269	0	-5	0	0.0%	-8.3%	0.0%
270	0	-5	0	0.0%	-12.2%	0.0%
271	0	0	0	0.0%	0.0%	0.0%
272	0	-5	-5	0.0%	-12.2%	-6.7%
273	0	0	0	0.0%	0.0%	0.0%
274	0	0	0	0.0%	0.0%	0.0%
275	0	-8	0	0.0%	-21.6%	0.0%
276	0	0	0	0.0%	0.0%	0.0%
277	0	0	0	0.0%	0.0%	0.0%
278	0	0	0	0.0%	0.0%	0.0%
279	0	0	0	0.0%	0.0%	0.0%
280	0	0	0	0.0%	0.0%	0.0%
281	0	0	-5	0.0%	0.0%	-7.7%
282	0	0	0	0.0%	0.0%	0.0%
283	0	0	0	0.0%	0.0%	0.0%
284	0	-4	0	0.0%	-8.9%	0.0%
285	0	0	0	0.0%	0.0%	0.0%
286	0	-5	0	0.0%	-7.7%	0.0%
287	0	0	0	0.0%	0.0%	0.0%
288	0	-5	0	0.0%	-7.7%	0.0%
289	0	-5	0	0.0%	-7.7%	0.0%
290	0	0	-5	0.0%	0.0%	-7.7%
291	0	0	0	0.0%	0.0%	0.0%
292	0	0	0	0.0%	0.0%	0.0%
293	0	0	0	0.0%	0.0%	0.0%
294	0	0	-2	0.0%	0.0%	-4.3%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
295	0	0	0	0.0%	0.0%	0.0%
296	0	-5	0	0.0%	-9.1%	0.0%
297	0	0	-2	0.0%	0.0%	-4.4%
298	0	0	-3	0.0%	0.0%	-7.3%
299	0	0	0	0.0%	0.0%	0.0%
300	0	0	0	0.0%	0.0%	0.0%
301	0	0	0	0.0%	0.0%	0.0%
302	0	-4	0	0.0%	-9.8%	0.0%
303	0	-1	0	0.0%	-5.9%	0.0%
304	0	-5	-5	0.0%	-14.7%	-7.7%
305	0	-2	0	0.0%	-4.2%	0.0%
306	0	0	0	0.0%	0.0%	0.0%
307	0	0	0	0.0%	0.0%	0.0%
308	0	0	0	0.0%	0.0%	0.0%
309	0	0	0	0.0%	0.0%	0.0%
310	0	0	-5	0.0%	0.0%	-14.3%
311	0	0	0	0.0%	0.0%	0.0%
312	0	0	-5	0.0%	0.0%	-9.1%
313	0	0	-5	0.0%	0.0%	-8.3%
314	0	0	0	0.0%	0.0%	0.0%
315	0	0	-5	0.0%	0.0%	-8.3%
316	0	-1	0	0.0%	-2.1%	0.0%
317	0	0	0	0.0%	0.0%	0.0%
318	0	-1	-5	0.0%	-2.3%	-7.7%
319	0	-3	0	0.0%	-7.9%	0.0%
320	0	-3	0	0.0%	-7.9%	0.0%
321	0	-1	-5	0.0%	-2.5%	-8.3%
322	0	-5	0	0.0%	-15.6%	0.0%
323	0	-3	0	0.0%	-8.6%	0.0%
324	0	0	0	0.0%	0.0%	0.0%
325	0	-3	0	0.0%	-9.1%	0.0%
326	0	-5	0	0.0%	-9.1%	0.0%
327	0	0	0	0.0%	0.0%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
328	0	-6	0	0.0%	-20.7%	0.0%
329	0	0	0	0.0%	0.0%	0.0%
330	0	-9	0	0.0%	-37.5%	0.0%
331	0	-3	-5	0.0%	-9.1%	-9.1%
332	0	-2	0	0.0%	-4.3%	0.0%
333	0	-2	0	0.0%	-4.1%	0.0%
334	0	-2	0	0.0%	-4.5%	0.0%
335	0	-1	0	0.0%	-2.4%	0.0%
336	0	0	0	0.0%	0.0%	0.0%
337	0	0	0	0.0%	0.0%	0.0%
338	0	0	-3	0.0%	0.0%	-10.0%
339	0	-8	0	0.0%	-34.8%	0.0%
340	0	-1	0	0.0%	-2.2%	0.0%
341	0	0	0	0.0%	0.0%	0.0%
342	0	0	-2	0.0%	0.0%	-4.5%
343	0	-1	0	0.0%	-2.5%	0.0%
344	0	0	0	0.0%	0.0%	0.0%
345	0	0	0	0.0%	0.0%	0.0%
346	0	0	0	0.0%	0.0%	0.0%
347	0	0	-2	0.0%	0.0%	-11.8%
348	0	0	0	0.0%	0.0%	0.0%
349	0	0	-1	0.0%	0.0%	-2.9%
350	0	0	-4	0.0%	0.0%	-13.8%
351	0	0	-7	0.0%	0.0%	-31.8%
352	0	-7	-1	0.0%	-31.8%	-2.2%
353	0	0	-2	0.0%	0.0%	-4.5%
354	0	0	-2	0.0%	0.0%	-5.0%
355	0	0	-2	0.0%	0.0%	-5.0%
356	0	-1	0	0.0%	-2.7%	0.0%
357	0	-2	0	0.0%	-5.7%	0.0%
358	0	-2	0	0.0%	-5.7%	0.0%
359	0	-1	-1	0.0%	-2.8%	-2.1%
360	0	-1	0	0.0%	-2.7%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
361	0	-4	-1	0.0%	-16.0%	-2.2%
362	0	-3	-1	0.0%	-16.7%	-2.2%
363	0	0	0	0.0%	0.0%	0.0%
364	0	0	-4	0.0%	0.0%	-13.8%
365	0	-1	0	0.0%	-2.7%	0.0%
366	0	0	-5	0.0%	0.0%	-20.8%
367	0	0	-1	0.0%	0.0%	-2.9%
368	0	0	-1	0.0%	0.0%	-2.8%
369	0	0	-1	0.0%	0.0%	-3.0%
370	0	0	-1	0.0%	0.0%	-2.9%
371	0	0	0	0.0%	0.0%	0.0%
372	0	0	-1	0.0%	0.0%	-2.8%
373	0	0	0	0.0%	0.0%	0.0%
374	0	0	-2	0.0%	0.0%	-5.3%
375	0	0	-1	0.0%	0.0%	-2.6%
376	0	-4	0	0.0%	-17.4%	0.0%
377	0	0	-1	0.0%	0.0%	-2.7%
378	0	0	-1	0.0%	0.0%	-3.6%
379	0	0	0	0.0%	0.0%	0.0%
380	0	0	0	0.0%	0.0%	0.0%
381	0	0	0	0.0%	0.0%	0.0%
382	0	0	0	0.0%	0.0%	0.0%
383	0	0	0	0.0%	0.0%	0.0%
384	0	0	0	0.0%	0.0%	0.0%
385	0	-5	0	0.0%	-7.1%	0.0%
386	0	0	0	0.0%	0.0%	0.0%
387	0	0	0	0.0%	0.0%	0.0%
388	0	0	0	0.0%	0.0%	0.0%
389	0	0	0	0.0%	0.0%	0.0%
390	0	0	0	0.0%	0.0%	0.0%
391	0	0	0	0.0%	0.0%	0.0%
392	0	0	0	0.0%	0.0%	0.0%
393	0	-4	0	0.0%	-12.5%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
394	0	-3	0	0.0%	-6.7%	0.0%
395	0	0	0	0.0%	0.0%	0.0%
396	0	-5	0	0.0%	-9.1%	0.0%
397	0	0	0	0.0%	0.0%	0.0%
398	0	0	0	0.0%	0.0%	0.0%
399	0	0	0	0.0%	0.0%	0.0%
400	0	-1	0	0.0%	-2.2%	0.0%
401	0	0	-1	0.0%	0.0%	-2.2%
402	0	-1	0	0.0%	-3.0%	0.0%
403	0	0	0	0.0%	0.0%	0.0%
404	0	0	0	0.0%	0.0%	0.0%
405	0	-1	0	0.0%	-2.9%	0.0%
406	0	-2	-1	0.0%	-11.8%	-2.8%
407	0	-3	0	0.0%	-14.3%	0.0%
408	0	0	-1	0.0%	0.0%	-2.9%
409	0	0	-1	0.0%	0.0%	-3.0%
410	0	0	0	0.0%	0.0%	0.0%
411	0	0	0	0.0%	0.0%	0.0%
412	0	-3	0	0.0%	-12.0%	0.0%
413	0	-1	0	0.0%	-3.3%	0.0%
414	0	0	-1	0.0%	0.0%	-2.9%
415	0	0	-1	0.0%	0.0%	-3.0%
416	0	0	-1	0.0%	0.0%	-3.0%
417	0	0	-1	0.0%	0.0%	-2.9%
418	0	0	-1	0.0%	0.0%	-2.9%
419	0	0	-1	0.0%	0.0%	-2.9%
420	0	0	0	0.0%	0.0%	0.0%
421	0	0	-3	0.0%	0.0%	-14.3%
422	0	0	-2	0.0%	0.0%	-8.0%
423	0	0	0	0.0%	0.0%	0.0%
424	0	0	0	0.0%	0.0%	0.0%
425	0	-1	0	0.0%	-2.3%	0.0%
426	0	-2	0	0.0%	-4.9%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
427	0	0	0	0.0%	0.0%	0.0%
428	0	0	-1	0.0%	0.0%	-2.4%
429	0	0	0	0.0%	0.0%	0.0%
430	0	0	0	0.0%	0.0%	0.0%
431	0	0	0	0.0%	0.0%	0.0%
432	0	-1	0	0.0%	-2.4%	0.0%
433	0	-1	0	0.0%	-2.1%	0.0%
434	0	-1	0	0.0%	-2.1%	0.0%
435	0	0	0	0.0%	0.0%	0.0%
436	0	-1	0	0.0%	-2.3%	0.0%
437	0	-1	0	0.0%	-2.5%	0.0%
438	0	-1	0	0.0%	-2.6%	0.0%
439	0	-1	0	0.0%	-2.6%	0.0%
440	0	-2	0	0.0%	-5.3%	0.0%
441	0	0	0	0.0%	0.0%	0.0%
442	0	-1	0	0.0%	-2.7%	0.0%
443	0	0	0	0.0%	0.0%	0.0%
444	0	0	0	0.0%	0.0%	0.0%
445	0	-2	0	0.0%	-6.7%	0.0%
446	0	0	0	0.0%	0.0%	0.0%
447	0	0	0	0.0%	0.0%	0.0%
448	0	-1	0	0.0%	-3.0%	0.0%
449	0	-1	0	0.0%	-3.1%	0.0%
450	0	0	0	0.0%	0.0%	0.0%
451	0	-3	0	0.0%	-11.1%	0.0%
452	0	-1	0	0.0%	-3.1%	0.0%
453	0	0	0	0.0%	0.0%	0.0%
454	0	0	-2	0.0%	0.0%	-7.7%
455	0	-2	-1	0.0%	-6.7%	-2.4%
456	0	-1	0	0.0%	-3.1%	0.0%
457	0	-2	0	0.0%	-11.1%	0.0%
458	0	0	0	0.0%	0.0%	0.0%
459	0	-1	0	0.0%	-3.7%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
460	0	0	-3	0.0%	0.0%	-15.0%
461	0	0	0	0.0%	0.0%	0.0%
462	0	-1	0	0.0%	-3.7%	0.0%
463	0	-2	0	0.0%	-8.0%	0.0%
464	0	0	0	0.0%	0.0%	0.0%
465	0	0	0	0.0%	0.0%	0.0%
466	0	0	0	0.0%	0.0%	0.0%
467	0	-1	-1	0.0%	-4.0%	-2.9%
468	0	0	-1	0.0%	0.0%	-3.1%
469	0	0	-1	0.0%	0.0%	-3.1%
470	0	0	0	0.0%	0.0%	0.0%
471	0	-1	-1	0.0%	-2.9%	-2.8%
472	0	0	0	0.0%	0.0%	0.0%
473	0	-2	0	0.0%	-9.1%	0.0%
474	0	0	0	0.0%	0.0%	0.0%
475	0	0	0	0.0%	0.0%	0.0%
476	0	0	0	0.0%	0.0%	0.0%
477	0	0	0	0.0%	0.0%	0.0%
478	0	0	0	0.0%	0.0%	0.0%
479	0	0	-1	0.0%	0.0%	-4.0%
480	0	0	-3	0.0%	0.0%	-15.8%
481	0	0	0	0.0%	0.0%	0.0%
482	0	0	-1	0.0%	0.0%	-3.4%
483	0	0	0	0.0%	0.0%	0.0%
484	0	-2	0	0.0%	-8.7%	0.0%
485	0	0	0	0.0%	0.0%	0.0%
486	0	0	0	0.0%	0.0%	0.0%
487	0	0	0	0.0%	0.0%	0.0%
488	0	0	0	0.0%	0.0%	0.0%
489	0	0	-1	0.0%	0.0%	-4.2%
490	0	0	0	0.0%	0.0%	0.0%
491	0	0	-1	0.0%	0.0%	-4.2%
492	0	0	0	0.0%	0.0%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
493	0	0	0	0.0%	0.0%	0.0%
494	0	0	0	0.0%	0.0%	0.0%
495	0	0	-1	0.0%	0.0%	-4.8%
496	0	0	-1	0.0%	0.0%	-4.5%
497	0	-1	-1	0.0%	-4.8%	-3.7%
498	0	0	0	0.0%	0.0%	0.0%
499	0	0	0	0.0%	0.0%	0.0%
500	0	-1	0	0.0%	-3.8%	0.0%
501	0	0	-1	0.0%	0.0%	-4.3%
502	0	0	-1	0.0%	0.0%	-4.5%
503	0	0	0	0.0%	0.0%	0.0%
504	0	0	-1	0.0%	0.0%	-5.6%
505	0	0	-1	0.0%	0.0%	-6.3%
506	0	-1	0	0.0%	-4.3%	0.0%
507	0	0	-2	0.0%	0.0%	-11.1%
508	0	0	0	0.0%	0.0%	0.0%
509	0	0	0	0.0%	0.0%	0.0%
510	0	0	0	0.0%	0.0%	0.0%
511	0	0	0	0.0%	0.0%	0.0%
512	0	0	0	0.0%	0.0%	0.0%
513	0	-1	0	0.0%	-3.0%	0.0%
514	0	0	-1	0.0%	0.0%	-2.5%
515	0	-1	-1	0.0%	-3.2%	-2.3%
516	0	0	0	0.0%	0.0%	0.0%
517	0	-1	0	0.0%	-3.0%	0.0%
518	0	-1	0	0.0%	-2.7%	0.0%
519	0	0	0	0.0%	0.0%	0.0%
520	0	-1	-1	0.0%	-3.2%	-2.3%
521	0	-1	0	0.0%	-3.1%	0.0%
522	0	0	0	0.0%	0.0%	0.0%
523	0	-1	-1	0.0%	-3.2%	-2.3%
524	0	-1	0	0.0%	-3.4%	0.0%
525	0	-1	0	0.0%	-2.9%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
526	0	-1	0	0.0%	-3.1%	0.0%
527	0	0	0	0.0%	0.0%	0.0%
528	0	0	-1	0.0%	0.0%	-3.3%
529	0	0	0	0.0%	0.0%	0.0%
530	0	0	0	0.0%	0.0%	0.0%
531	0	-2	0	0.0%	-10.0%	0.0%
532	0	-1	0	0.0%	-3.6%	0.0%
533	0	0	0	0.0%	0.0%	0.0%
534	0	0	0	0.0%	0.0%	0.0%
535	0	0	0	0.0%	0.0%	0.0%
536	0	0	-1	0.0%	0.0%	-4.2%
537	0	0	0	0.0%	0.0%	0.0%
538	0	0	-1	0.0%	0.0%	-4.0%
539	0	0	0	0.0%	0.0%	0.0%
540	0	0	0	0.0%	0.0%	0.0%
541	0	0	0	0.0%	0.0%	0.0%
542	0	0	0	0.0%	0.0%	0.0%
543	0	0	-1	0.0%	0.0%	-4.2%
544	0	-1	0	0.0%	-4.2%	0.0%
545	0	0	0	0.0%	0.0%	0.0%
546	0	0	-1	0.0%	0.0%	-3.8%
547	0	0	0	0.0%	0.0%	0.0%
548	0	0	0	0.0%	0.0%	0.0%
549	0	0	-1	0.0%	0.0%	-4.2%
550	0	0	-1	0.0%	0.0%	-4.3%
551	0	-1	0	0.0%	-5.0%	0.0%
552	0	0	0	0.0%	0.0%	0.0%
553	0	0	0	0.0%	0.0%	0.0%
554	0	-1	0	0.0%	-5.0%	0.0%
555	0	0	0	0.0%	0.0%	0.0%
556	0	0	0	0.0%	0.0%	0.0%
557	0	0	0	0.0%	0.0%	0.0%
558	0	0	0	0.0%	0.0%	0.0%

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	IZ	MZ	OZ	IZ	MZ	OZ
559	0	0	0	0.0%	0.0%	0.0%
560	0	-1	0	0.0%	-4.5%	0.0%
561	0	0	0	0.0%	0.0%	0.0%
562	0	0	0	0.0%	0.0%	0.0%
563	0	0	0	0.0%	0.0%	0.0%
564	0	0	0	0.0%	0.0%	0.0%
565	0	-1	0	0.0%	-5.0%	0.0%
566	0	0	0	0.0%	0.0%	0.0%
567	0	0	-1	0.0%	0.0%	-5.3%
568	0	0	0	0.0%	0.0%	0.0%
569	0	0	0	0.0%	0.0%	0.0%
570	0	-1	0	0.0%	-5.6%	0.0%
571	0	0	0	0.0%	0.0%	0.0%
572	0	0	0	0.0%	0.0%	0.0%
573	0	0	0	0.0%	0.0%	0.0%
574	0	0	-1	0.0%	0.0%	-4.2%
575	0	-1	0	0.0%	-4.5%	0.0%
576	0	0	0	0.0%	0.0%	0.0%
577	0	0	0	0.0%	0.0%	0.0%
578	0	0	0	0.0%	0.0%	0.0%
579	0	0	0	0.0%	0.0%	0.0%
580	0	0	0	0.0%	0.0%	0.0%
581	0	0	0	0.0%	0.0%	0.0%
582	0	0	0	0.0%	0.0%	0.0%
583	0	0	0	0.0%	0.0%	0.0%
584	0	0	0	0.0%	0.0%	0.0%

16.2 Non-natural gas LUP Zones

16.2.1 PIPIN V3.04

Table 26 contains the LUP zone results for the non-natural gas pipelines, using PIPIN V3.04 to generate the failure rates.

Table 26 LUP zones using failure rates calculated using PIPIN V3.04

Pipeline	Substance	Non-natural gas MISHAP LUP zones (m) from PIPIN V3.04		
		Inner	Middle	Outer
9669	Ethylene	130	190	235
11906	Propane	24	28	36
11885	N-butane	29	75	380
11886	Propane	27	44	65
7129	Ethylene	110	150	195
10021	Ethylene	32	70	85
6799	Propylene	36	37	75
7335	Ethylene	47	47	70
12855	Ethylene	50	90	105
6978	Propane	27	42	60
12592	Propane	25	38	65
6713	Ethylene	47	47	75
8395	Propane	23	29	50
6904	Ethylene	54	130	150
7338	Propane	55	205	300
7340	N-butane	55	855	2050
6802	Ethylene	44	85	100

16.2.2 PIPIN V3.1

Table 27 contains the LUP zone results for the non-natural gas pipelines, using PIPIN V3.1 to generate the failure rates.

Table 27 LUP zones using failure rates calculated using PIPIN V3.1

Pipeline	Substance	Non-natural gas MISHAP LUP zones (m) from PIPIN V3.1		
		Inner	Middle	Outer
9669	Ethylene	125	190	230
11906	Propane	24	28	36
11885	N-butane	29	75	360
11886	Propane	27	43	65
7129	Ethylene	110	150	190
10021	Ethylene	32	70	85

Pipeline	Substance	Non-natural gas MISHAP LUP zones (m) from PIPIN V3.1		
		Inner	Middle	Outer
6799	Propylene	36	37	75
7335	Ethylene	47	47	70
12855	Ethylene	50	85	105
6978	Propane	27	42	60
12592	Propane	25	37	65
6713	Ethylene	47	47	75
8395	Propane	23	28	50
6904	Ethylene	54	130	150
7338	Propane	55	200	295
7340	N-butane	55	745	2050
6802	Ethylene	44	85	100

16.2.3 LUP zone comparison

The LUP zones detailed in Sections 16.2.1 and 16.2.2 have been compared. The results of the comparison are shown in table 22 where the differences are calculated as (new – old) and the percentage differences are (new – old) / old. “New” represents the results from MISHAP using the failure rates calculated by PIPIN V3.1 and “old” refers to the LUP zones from MISHAP using the failure rates calculated by PIPIN V3.04.

Table 28 Comparison of LUP zones for the non-natural gas pipelines

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	Inner	Middle	Outer	Inner	Middle	Outer
9669	-5.0	0.0	-5.0	-3.8	0.0	-2.1
11906	0.0	0.0	0.0	0.0	0.0	0.0
11885	0.0	0.0	-20.0	0.0	0.0	-5.3
11886	0.0	-1.0	0.0	0.0	-2.3	0.0
7129	0.0	0.0	-5.0	0.0	0.0	-2.6
10021	0.0	0.0	0.0	0.0	0.0	0.0
6799	0.0	0.0	0.0	0.0	0.0	0.0
7335	0.0	0.0	0.0	0.0	0.0	0.0
12855	0.0	-5.0	0.0	0.0	-5.6	0.0
6978	0.0	0.0	0.0	0.0	0.0	0.0
12592	0.0	-1.0	0.0	0.0	-2.6	0.0

Pipeline	Difference (m) in LUP zones sizes			% difference in LUP zone sizes		
	Inner	Middle	Outer	Inner	Middle	Outer
6713	0.0	0.0	0.0	0.0	0.0	0.0
8395	0.0	-1.0	0.0	0.0	-3.4	0.0
6904	0.0	0.0	0.0	0.0	0.0	0.0
7338	0.0	-5.0	-5.0	0.0	-2.4	-1.7
7340	0.0	-110.0	0.0	0.0	-12.9	0.0
6802	0.0	0.0	0.0	0.0	0.0	0.0

The Health and Safety Executive (HSE) uses a computer code PIPIN (PIPeline INtegrity) to determine the failure frequencies of major accident hazard (MAH) pipelines for land use planning (LUP) purposes. PIPIN calculates the failure rates of pipelines for various modes of failure, including that of third party activity (TPA). The model for TPA requires the fracture toughness of the pipeline steel as an input. This is known to be adversely affected by the presence of hydrogen and must therefore be modified for the PIPIN approach to be applicable to hydrogen pipelines.

A stepwise approach for accounting for the effect of hydrogen on the fracture toughness of pipeline steels for use within PIPIN has been proposed. This is based on the use of the Kiefner correlation between Charpy impact energy and fracture toughness, which is currently used in PIPIN. The estimated fracture toughness is then reduced by a specified factor to account for the effect of hydrogen. Checks against a published data set on the fracture toughness of relevant steels in 100 bar hydrogen showed that the mean predicted toughness using the developed method was 1.29 times the actual measured toughness.

The proposed approach applies to estimations of failure frequencies for LUP purposes, where the condition of the pipe is unknown. The level of conservatism is therefore considered acceptable. The approach is not applicable to fitness-for-service determination for pipes containing known or postulated damage.

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