DNV·GL

RISK ASSESSMENT OF MULTI OCCUPANCY BUILDINGS

Development of the Risk Assessment Procedure and Spreadsheet

National Grid

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Objective: To develop a risk assessment procedure that will be consistent with the HSE template for risk assessment. This will mean that the results of high rise / complex distribution system surveys will be recorded and will identify measures that are currently being used to manage the risks, any additional measures that could be implemented to manage the risks and also any resulting actions with appropriate timescales

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☒ Unrestricted distribution within DNV GL
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1.1	31/03/17	Inclusion of Complex Networks Methodology	Tahir Bhola & Nick Cowling	Phil Baldwin	

Contents

1 EXECUTIVE SUMMARY

Much work has been done to examine the risks associated with gas in flats including assessing idealised methodologies of ranking the risk [1][2][3][4].

To assist with the planning of maintenance works, National Grid undertake regular surveys of multi occupancy buildings that have gas supplies. The information that is collected is intended to feed into a risk ranking methodology that was originally developed by DNV GL for National Grid's assets within high rise buildings. During the original high rise survey process the National Grid personnel collecting the information have found some of the data required by the risk ranking methodology is difficult to collect and in a lot of cases it has not been possible to provide suitable inputs.

A spreadsheet has been developed which allows data from high rise surveys to be captured and recorded. Using this information, 'Priority' scores (previously referred to 'Risk Ranking' score) for buildings are generated and breakdown for individual assets given. For high rise buildings, if the value of this score is 210,000 or more, it is recommended a risk assessment is undertaken. If the score is less than 210,000 a re-survey should be undertaken within 5 years and if the score is less than 100,000 a re-survey should be undertaken within 10 years. It is recommended these values should be reassessed shortly after implementation when more building assessment scores are available.

National Grid also have assets within buildings that are not high rise buildings. National Grid have classed these assets as complex distribution systems (CDS). To date, all CDS are located within large shopping centres. Minor modifications have been made to the high rise spreadsheet to allow a different spreadsheet to be used for capturing and recording additional data for CDS surveys. As for the high rise spreadsheet, Priority scores for buildings are generated and a breakdown for individual assets given. Only 15 buildings with CDS have been identified to date. Additional comprehensive searches are scheduled to establish the number of assets likely to be present. Upon completion of these searches, initial surveys and generation of Priority scores, a review will be carried out to finalise the appropriate criteria for survey frequencies and the requirements for further risk assessment.

The data entered into the spreadsheets allows the survey information to be captured and analysed in detail. If a risk assessment is required, this information also allows an assessment of each asset to be undertaken so that appropriate risk reduction measures can be identified and/or implemented. The risk assessment process and any identified actions are also incorporated into the spreadsheet. This new two stage process will assist with the planning of maintenance activities to National Grid's assets within high rise and CDS buildings.

2 INTRODUCTION

To comply with current legislation, National Grid Gas, as a gas transporter, has an obligation to satisfy the requirements of Regulation 13 of the Pipeline Safety Regulations 1996 (PSR), and ensure pipelines are 'maintained in an efficient state, in efficient working order and in good repair'.

There are approximately 2,800 blocks of high rise flats throughout the country, many of which were built over 40 years ago. Much work has been done to examine the risks associated with gas in flats including assessing idealised methodologies of ranking the risk [1][2][3][4].

Furthermore, in 2016, a number of additional distribution networks in multi occupancy buildings (mainly shopping centres) were identified by National Grid. National Grid have classed these assets as complex distribution systems (CDS).

To assist with the planning of maintenance works, National Grid undertake regular surveys of buildings that have gas supplies. The information that is collected is intended to feed into a risk ranking methodology that was originally developed by DNV GL for National Grid's assets within high rise buildings. During the survey process the National Grid personnel collecting the information have found that some of the data required by the risk ranking methodology is difficult to collect and in a lot of cases it has not been possible to provide suitable inputs.

National Grid have asked DNV GL to develop a risk assessment procedure that is consistent with the HSE template for risk assessment so that the results of the surveys will be recorded and will identify measures that are currently being used to manage the risks. Any additional measures that could potentially be implemented to manage the risks and any resulting actions with appropriate timescales can also be captured.

This report describes:

- Previous work and conclusions (Section 0)
- The practical risk ranking methodology used to calculate a 'priority' score (previously referred to 'Risk Ranking' score) for high rise buildings (Section 0)
- How the priority score is used to determine whether a risk assessment is undertaken for high rise buildings (Section 0)
- Additional items to be included when CDS buildings are surveyed (Section 6)
- The risk assessment procedure for high rise buildings and CDS (Section 7).

3 SUMMARY OF PREVIOUS RELEVANT STUDIES

3.1 FN Calculation for High Occupancy Buildings

The conclusions of work [1] undertaken to produce an FN calculation method for explosions in high occupancy buildings considered events in which building damage occurred, including gas explosions, non-gas explosions and earthquakes. The methodology took into account the following observations made after events that damaged high occupancy (not limited to high rise) buildings:

- The proportion of building occupants killed is relatively small, even for events in which building destruction occurs.
- The likelihood of fatalities increases with the explosion severity (that is overpressure generated), noting that:
  - Explosions are more likely to be severe where a cellar is present
  - Explosions are more severe in concrete or brick constructed buildings (as the walls are load bearing) compared to those in steel framed buildings
- The number of fatalities predicted is reduced if the ratio of room width/building frontage is less than 0.5

3.2 Risk Assessment Methodology and ALARP Calculation

An approach [2] was formulated to assess the risk due to explosions in high rise buildings following failures on gas supplies within those buildings. The assessment takes into account all the pipework between the distribution main and the Emergency Control Valve, including the below ground pipework, risers and laterals. The outputs include an individual risk prediction for a resident of each storey. The societal risk is calculated as FN data for the building as a whole, and can also be expressed as an expectation value of the number of fatalities occurring per year as a result of failures on the service pipework, or in terms of the frequency of fatal explosions.

The methodology has then been used to assess representative generic scenarios [4]. In summary:

- The calculated risk levels associated with the vast majority of National Grid's services to high rise domestic properties lie in the broadly acceptable region and, in view of the current practices and control measures in place, no further demonstration that these risks are ALARP should be required, other than continued operation to current good practice.
- For specific scenarios, the levels of risk fall into the ALARP demonstration region and work has been undertaken to consider the costs and benefits of risk mitigation measures. These calculations suggest that in many cases the costs of mitigation measures (i.e. complete replacement) are disproportionate to the reduction in risk and, therefore, need not be undertaken on a risk reduction basis.
- None of the scenarios considered give rise to calculated risk levels that would be classified as unacceptable (i.e. where individual risk levels are greater than 1×10^{-4} per year or where societal risk levels are greater than 1×10^{-2} per year).

However, this model assumes that complete destruction of the building does not occur. Therefore fatalities are only predicted to occur on the ground floor when an explosion occurs in a basement (it is assumed the basement is unoccupied).

3.3 Prioritisation of the Replacement / Surveys for Supplies to High Rise Buildings

Initially, a qualitative risk assessment was undertaken to enable the risks associated with common riser arrays in high rise buildings containing domestic properties to be ranked [3]. The risk ranking system was intended to be used to rank the replacement of service pipes according to the risks associated with gas riser arrays in the building.

The risk ranking system is based on a subjective assessment of the impact of risk factors and mitigating measures on the likelihood of an explosion occurring as a result of a gas leak from the riser arrays, which is calculated relative to a benchmark installation.

In 2011, the model was extended to include the buried supply pipe leading to the building and the laterals to each property from each riser. The risk scoring system for these assets was also based on a similar subjective assessment described above. To obtain an overall building score, the scores for each asset were summed. This overall score was used to rank the buildings, which in turn was used to determine the date of the next survey. The risk ranking methodology is described in Appendix A.

3.4 Summary of Previous Work

Whilst unlikely, the work described in Section 3.1 identifies that it is possible for multiple fatalities ('high consequence') to occur in high rise buildings. The likelihood of these events increases where cellars are present and/or the building has load bearing walls. A recent example is the gas explosion which occurred in Harlem, New York on 12th March 2014 [5].

The work described in Section 3.2 indicates that the majority of National Grid's high rise buildings are likely to lie in the 'broadly acceptable' region of HSE's risk criteria. For some scenarios where the risks lie within the ALARP region, it was identified that the cost of mitigation measures, such as replacing an internal riser system with an external riser system, are likely to be disproportionate to the reduction in risk. It should be noted however that this model does not take into account the possibility of high consequence events and covers only representative scenarios.

To comply with current legislation, (see Section 0) National Grid have to ensure pipelines are 'maintained in an efficient state, in efficient working order and in good repair'. The work described in Section 3.3 provides a practical approach which allows each of National Grid's high rise buildings to be ranked following the completion of a survey. The risk ranking method incorporates elements for high consequence events, the level of corrosion on National Grid's assets and compliance with IGEM/G/5. However, there are two issues National Grid have encountered with this approach:

- It is not always possible to collect the minimum amount of data that is required for a valid score to be produced
- where valid scores are produced, assessing the level of maintenance required (i.e. localised repairs or complete replacement) can be difficult.

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4 HIGH RISE RISK RANKING SCORES

National Grid provided DNV GL with an output of the risk ranking scores for every building on their high rise database (June 2015). The risk ranking scores are based on the previous model developed by DNV GL (see Section 3.3). The overall risk ranking scores include contributions from the supply pipes, risers and laterals. A breakdown of the individual asset score can only be obtained for the risers.

A summary of the risk ranking scores as at June 2015 is provided in Table 1.

Table 1 Summary Surveys Undertaken as June 2015

Aspect	Number of Buildings	Comment
Total buildings on the database	2835	National Grid's portfolio of high rise buildings with gas supplies
Buildings where the survey has not been completed	588	Generates a risk ranking score of 99,999,999. See Section 0.
Buildings with a valid risk ranking score	953	Score generated by successful collections of minimum survey data. See Section 0.
Buildings with no risk ranking score	1294	It is assumed these buildings were surveyed prior to 2011 before the current survey procedure was brought in. Therefore it is known that these buildings contain assets of National Grid and will be surveyed in due course. See Section 4.3.

4.1 Surveys Not Completed

As indicated in Section 0, National Grid personnel have sometimes been unable to obtain all the data needed to produce a valid risk ranking score. A summary of why surveys have not been completed is given in Table 2. Those highlighted in:

- Green, are buildings where a risk assessment approach (see Section 0) could be used to determine the work to be undertaken
- Orange, are out of scope
- White, will require a survey to be undertaken.

Table 2 Summary of Where Building Surveys Not Completed

Aspect	No. of Buildings
Unable to gain access	117
Unknown	78
0% Seen or 0% of Internal Vertical Riser, Horizontal Riser, External Vertical Riser Seen	163
Less than 6 storeys	50
Building Demolished	47
No Gas	37
Gas to separate Central Boiler Only	23

Aspect	No. of Buildings
Failed for Other Reason	21
I&C	21
Unable to complete in 3 Visits	13
Invalid address	10
Gas Supply to Separate Meter House	6
It has been advised the building is susceptible to disproportionate collapse	2

4.2 Valid Risk Ranking Scores

The output for valid risk ranking scores in the current database at present only provides an overall score for the building (i.e. supply pipe score + riser score + lateral score) and an individual score for each of the risers. No information is provided on the scores for the supply pipe(s) and lateral(s). Of the 954 valid risk ranking scores generated:

- 87 of the surveys the risk ranking score from the risers contributed to more than 50% of the overall building score
- 43 contribute to more than 80% of the risk ranking score.

The top 10 buildings where the biggest contribution is from the risers are shown in Table 3.

Table 3 Top 10 High Rise Buildings where Risers Contribute Most to the Overall Building Score

Building ID	Address 1	Postcode	LDZ	Storeys	No. of Risers	Risk Ranking Score
80	Larchwood House	IG7 4AY	NL	10	4	5,753
24843	Rochford	N17	NL	6	9	1,747,003
100000000337	Shackleton House	NW10 8EH	NL	9	7	9,555,704
100000000662	Hackwood House	B69 1EG	WM	13	6	322,836
100000001142	Falcon Lodge	W9 3TA	NL	8	1	704
100000001145	Nuffield Lodge	W9 3TP	NL	7	1	33,821
100000001146	Johnson Lodge	W9 3TJ	NL	7	1	704
100000001147	Livingstone Lodge	W9 3TN	NL	7	1	238
100000001149	Nightingale Lodge	W9 3TW	NL	8	1	704
100000001590	87	SW3 2RD	NL	6	2	6,077,150

The majority of lateral lengths are small (assumed to be less than 0.5 m), therefore it can be deduced that the largest contributor to the scores is due to the supply pipe(s). In a considerable number of cases this occurs as a result the supply pipe material being recorded as metallic or unknown.

For example it is possible for the current risk ranking methodology to indicate replacement of risers which are already located externally if the material of the supply pipe has been entered as being

unknown e.g. Robin House. In this case it would be more cost effective to determine the supply pipe material and:

- if PE, the survey can be updated (the risk ranking score will reduce), or
- if metallic, it may be more cost effective to replace the supply pipes in line with National Grid procedures.

The adoption of a risk assessment procedure as an additional step for buildings with high scores will enable mitigation measures to be identified that are currently being used to manage the risks and any additional measures that are appropriate and could be implemented to manage the risks. The output of a risk assessment will provide a set of actions with appropriate timescales and a corresponding date for a re-survey to be undertaken.

Note: Discussion of what constitutes a high score is provided in Section 0.

4.3 Buildings with No Risk Ranking Score

There are a number of buildings which are yet to be surveyed. An issue with the current risk ranking software is that a breakdown of the score is not provided. Therefore, the software National Grid use needs to be developed to provide a breakdown for each asset. This will assist in identifying the largest contributors to the overall risk ranking score for the building if undertaking the risk assessment. The majority of the factors used in the risk ranking calculation described in Appendix A have been used to calculate a 'Priority' score for these buildings.

Note: Form this point on, 'Priority' is used instead of 'risk ranking'

5 RISK ASSESSMENT OF HIGH RISE BUILDINGS WITH A HIGH PRIORITY SCORE

5.1 Criteria for Risk Assessment

Table 4 is taken from previous work (see Section 3.3) following a valid priority score being produced for a building.

Table 4 Previous Re-survey Frequencies based on Priority Score (previously referred to as Risk Ranking Score)

Inspection Interval	Min Building Priority Score	Max Building Priority Score
Up to 1 year	5,000,000	99,999,999
Up to 2 years	1,500,000	4,999,999
Up to 3 years	210,000	1,499,999
Up to 5 years	130,000	209,999
Up to 10 years	0	129,999

Based on this information the following changes in Table 5 are suggested to incorporate a criterion for risk assessment.

Table 5 Suggested Re-Survey Frequencies and Risk Assessment Criteria based on Priority Score

Inspection Interval	Min Building Priority Score	Max Building Priority Score
Undertake risk assessment and deduce survey interval on outcome or identify additional risk mitigation measure for implementation	210,000 or: ∞ if any pipe has severe corrosion ∞ If a PIV is missing ∞ If 0% seen of any riser ∞ If supervisor deems it necessary	99,999,999
Up to 5 years	100,000	209,999
Up to 10 years	0	99,999

Using the high rise database provided by National Grid (June 2015), Figure 1 shows how many buildings would currently fall under each category and how it would be extrapolated if applied across all high rise buildings.

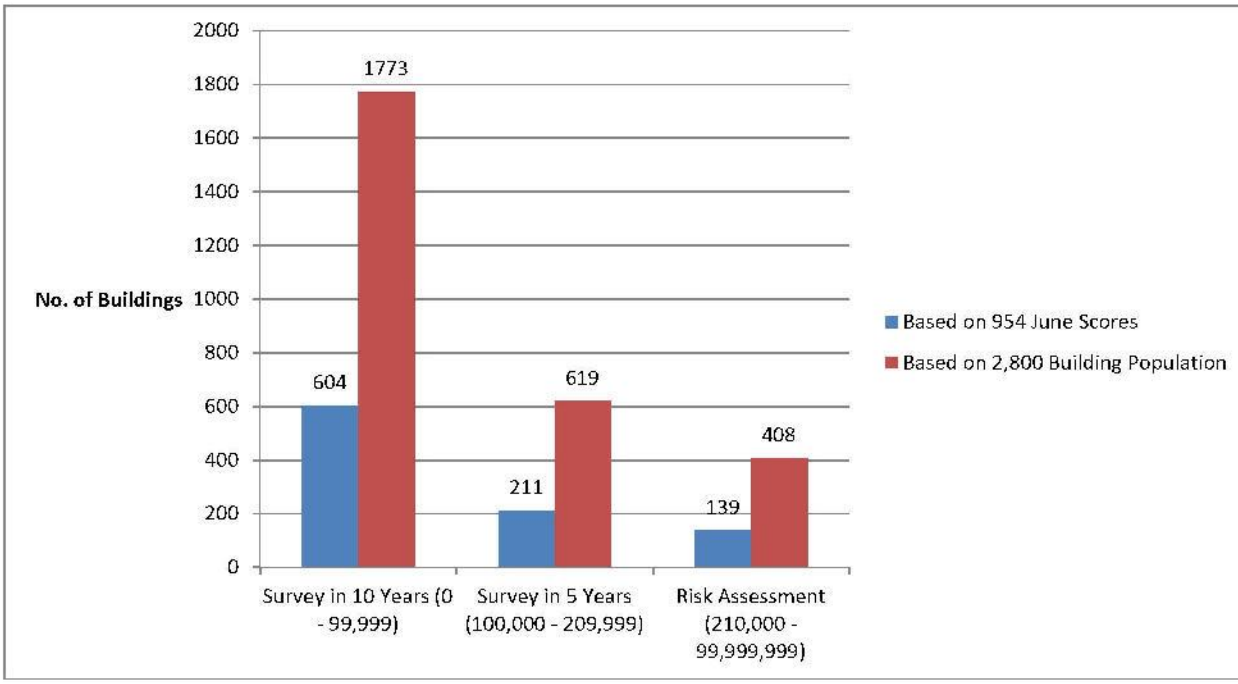

Figure 1 Predicted Number of Buildings in Each Category Suggested in Table 5

5.2 Overview of Revised Risk Management Procedure

An overview of the revised procedure is given in Figure 2.

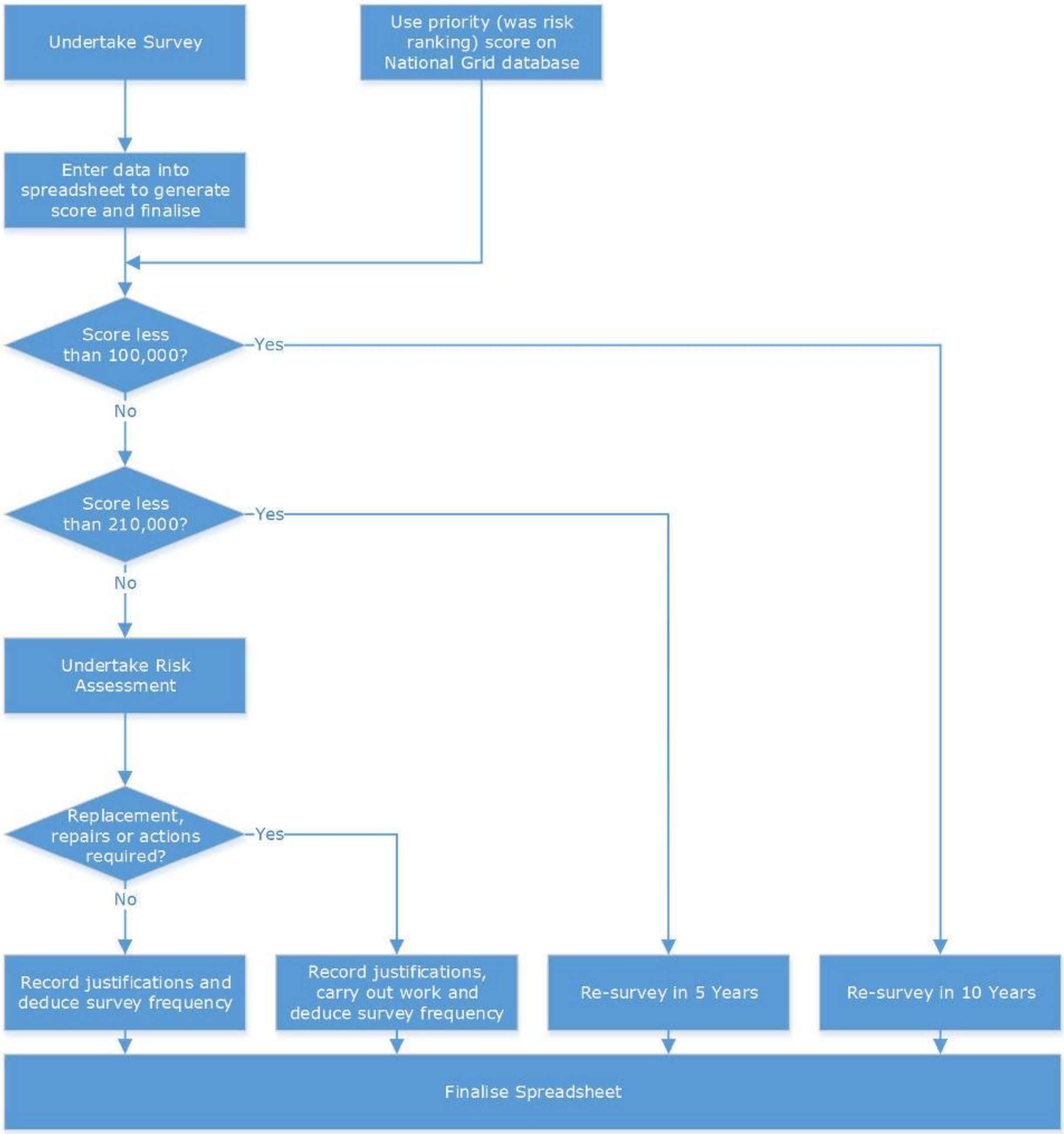

Figure 2 Survey, Risk Assessment, Repairs and Re-survey Procedure

6 CDS SURVEYS AND RISK ASSESSMENT CRITERIA

In 2016, 15 multi occupancy buildings (mainly shopping centres) with distribution networks were identified by National Grid. National Grid have classed these assets as complex distribution systems (CDS). Initially these were subject to the approach detailed in this document for high rise buildings. However, a number of additional and more asset specific concerns were highlighted during a review process (workshop held in January 2017). As a result, variations in the survey methodology for CDS have been implemented.

The additional checks and factors that are used in the CDS spreadsheet are summarised in the following sections.

6.1 Survey Confidence for Inaccessible Pipelines

The original approach for 'survey confidence' is detailed in Appendix A. At the workshop, concern was raised regarding the inability to fully inspect pipes at high level or in inaccessible areas. Whilst surveyors could view the pipeline, surveyors were not confident that joints were not leaking. To address this concern an additional input in both the riser information (column M) and lateral information (column L) worksheets has been included to capture the effectiveness of any pipe inspections. The factors are given below.

Factors that affect confidence in the survey data	Value assigned in scoring system
Percentage of riser surveyed with a gas detector	1 if over 75%, 1.1 if 50 to 75%, 1.3 if 25 to 50%, 1.5 if under 25% and 20 if 0%

6.2 Inaccessible Emergency Control Valves

At the workshop, there were examples where the emergency control valve (ECV) was not readily accessible. To address this concern, an additional input was included to capture whether ECVs are accessible (column Y, lateral information worksheet). This doesn't change the risk ranking score but generates a warning flag in the input summary worksheet where ECVs cannot be easily accessed.

6.3 Pipelines Located in Tunnels or Ducts

At the workshop, DNV GL noted that there were a number of occasions where notable lengths of pipework were present in long horizontal ducts / service tunnels. This arrangement can increase the severity of an explosion, To address this concern, an additional input to capture the presence of pipes in service tunnels / ducts (column O, riser information worksheet & column N, lateral information worksheet) was included. Where these exist, the risk ranking score is elevated to reflect the increased likelihood of the build up of flammable mixtures should a gas escape occur. The factors are given below.

Factors that affect explosion severity	Value assigned in scoring system
Pipeline located in tunnel	1 if No, 10 if Yes

6.4 Larger Diameter Pipelines

At the workshop it was noted that generally larger diameter pipes are within CDS buildings. Larger diameter pipes have larger wall thickness. Therefore, the corrosion failure factor (column AX, riser

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information worksheet & column AK, lateral information worksheet) has been reduced for larger diameter (>8") pipes.

However, in event of a complete break of a large diameter pipeline there will be larger volume of gas released leading to the formation of flammable clouds within shorter timescales and/or with greater flammable volumes. Therefore, the pipe diameter factor for high consequence events (column BO, riser information worksheet & column AV, lateral information worksheet) has been extended for larger diameter (>6") pipe.

6.5 Identification of Pipelines in CDS Buildings

In the shopping centres reviewed at the workshop it was noted that it can be difficult on occasions to identify which pipelines contain gas. For example, it was noted that in one case a water valve had been installed on a gas pipeline. To address this concern a further check has been added to the spreadsheet (Row 29, building description sheet). This doesn't change the risk ranking score but generates a warning flag where gas pipework is not easily distinguishable from other utilities.

6.6 Criteria for Risk Assessment

As for the high rise spreadsheet, Priority scores for buildings are generated and a breakdown for the individual assets given. At present (March 2017), only 15 buildings with CDS have been identified. Further comprehensive searches are scheduled to be carried out. Upon completion of these searches and an initial assessment of the Priority scores, a review will be carried out to establish an appropriate criterion for these types of assets and their corresponding survey frequencies using a larger data set with a greater view on the types of asset integrity threats likely to be encountered.

In the meantime, good practice will be employed to promptly resolve obvious issues related to asset integrity that are identified e.g. severe corrosion.

7 RISK ASSESSMENT PROCEDURE

7.1 Process

A spreadsheet has been developed that produces a priority score for the building. A guide on how to use this is provided in Appendix B. Note that as the priority score does not exactly replicate the previous method described in Appendix A. It is suggested that the scores incorporated within the risk assessment in Section 0 are reviewed and adjusted if necessary once the procedure has been used on a number of buildings.

Where a building with a high priority score is identified and a risk assessment is deemed to be required, the following process should be followed:

- Obtain Survey Report, ESRI map, Aerial View, Street View, other photos and details of other issues
- Hold a Risk Assessment meeting with personnel who have visited the site, with the National Grid supervisor appointed as Chair for the meeting (In the initial rollout, DNV GL may support this role)
- Review the data entry input and priority score for each asset
- Fill out the form for each asset (or group of assets where they have similar properties)
- Identify the threat(s) to each asset
- Identify the potential consequence(s)
- List any mitigation measure(s)
- Review the score (if manually altered the change must be recorded under action required)
- Identify any other additional actions and when they should be completed by
- Complete the Summary Sheet including any justification for action taken
- Finalise and save the spreadsheet for future reference.

7.2 Risk Assessment Development

A workshop (23rd July 2015) and two trials (5th and 7th August) were held, with current surveys used as examples to identify potential site specific threats to National Grid assets (supply pipe, riser and lateral) and associated consequences that could occur in high rise buildings. By assigning impact and likelihood values to each combination of consequences, threat and asset type, a qualitative measure of risk can be obtained by multiplying the impact value by the likelihood value. This calculation can be also multiplied by a mitigation measure factor (i.e. a number less than 1) so any benefit can be given for any action taken or planned by National Grid.

Note that the suggested impact, likelihood and mitigation / action scorings (see Sections 7.3, 0 and 0) have no correlation with the priority score, but are an additional measure of risk reduction to record those measures which have been identified as being in place or implemented.

7.3 Impact Values

7.3.1 Potential Consequences

The following potential consequences (dependent on the riser layout) were identified:

- Gas tracking into the building from outside
- Gas leak from small hole
- Flash fire - short hazard range
- Large Gas leak inside the building/dwelling
- Small Gas leak inside the building/dwelling
- Increased stress on joints leading to failure
- Gas fuelled fire
- Large Gas leak to atmosphere
- Small Gas leak to atmosphere
- Large Gas leak into enclosed space
- Small Gas leak into enclosed space

7.3.2 Impact Values Used in the Spreadsheet

The impact values depend on the combination of asset and potential consequence. An assessment has been made and value has been assigned to each, then multiplied and divided by 5 to give a value between one and five. The impact values assigned to each combination is given in Table 6.

Table 6 Impact Values Used in the Spreadsheet

Asset	Value Assigned	Potential Consequences	Value Assigned	Impact Value Used
Supply Pipe	5	Gas tracking into the building from outside	5 if basement present, 4 otherwise	*5 or 4*
Supply Pipe	5	Gas leak from small hole	3 if basement present, 2 otherwise	*3 or 2*
Supply Pipe	5	Flash fire - short hazard range	3	*3*
Internal Riser Common Area	2	Gas leak inside the building (Large)	4 if basement present, 3 otherwise	*1.6 or 1.2*
Internal Riser Common Area	2	Gas leak inside the building (Small)	3 if basement present, 2 otherwise	*1.2 or 0.8*
Internal Riser Common Area	2	Increased stress on joints leading to failure	5 if basement present, 4 otherwise	*2 or 1.6*
Internal Riser Common Area	2	Gas fuelled fire	4	*1.6*
Internal Riser Within Property	4	Gas leak inside the dwelling (Large)	4	*3.2*
Internal Riser Within Property	4	Gas leak inside the dwelling (Small)	3	*2.4*
Internal Riser Within Property	4	Increased stress on joints leading to failure	5 if basement present, 4 otherwise	*4 or 3.2*
Internal Riser Within Property	4	Gas fuelled fire	4	*3.2*
Internal Riser Within Duct	3	Gas leak inside the building (Large)	4 if basement present, 3 otherwise	*2.4 or 1.8*
Internal Riser Within Duct	3	Gas leak inside the building (Small)	3 if basement present, 2 otherwise	*1.8 or 1.2*
Internal Riser Within Duct	3	Increased stress on joints leading to failure	5 if basement present, 4 otherwise	*3 or 2.4*
Internal Riser Within Duct	3	Gas fuelled fire	4	*2.4*
External Riser	1	Gas leak to atmosphere (Large)	2	*0.4*
External Riser	1	Gas leak to atmosphere (Small)	1	*0.2*
External Riser	1	Gas leak into enclosed space (Large)	3	*0.6*
External Riser	1	Gas leak into enclosed space (Small)	2	*0.4*
External Riser	1	Increased stress on joints leading to failure	5 if basement present, 4 otherwise	*1 or 0.8*
External Riser	1	Gas fuelled fire	4	*0.8*
Laterals	3	Gas leak inside the dwelling (Large)	4	*2.4*
Laterals	3	Gas leak inside the dwelling (Small)	3	*1.8*
Laterals	3	Increased stress on joints leading to failure	5 if basement present, 4 otherwise	*3 or 2.4*
Laterals	3	Gas fuelled fire	4	*2.4*

7.4 Likelihood Values

The following threats to the integrity of gas supplies associated with high rise buildings were identified:

- 3rd Party Interference
- Impact Damage
- Severe Corrosion
- Moderate Corrosion
- Superficial Corrosion
- Potential for Corrosion

- Internal fires
- External fires
- Small (threaded) joint failure
- Large (full bore) joint failure
- Vandalism
- Potentially unsupported pipe

For each of the threats, base values have been assigned as shown in Table 7.

Table 7 Likelihood Values used in the Spreadsheet

Threat	Likelihood Value
3rd Party Interference	3
Impact Damage	3
Severe Corrosion	5
Moderate Corrosion	4
Superficial Corrosion	3
Potential for Corrosion	2
Internal Fires	2
External Fires	1
Small (threaded) joint failure	4
Large (full bore) joint failure	3
Vandalism	3
Potentially unsupported pipe	3

7.5 Mitigation Measures and Actions

The following mitigation measures and actions were identified with the reduction factors used shown in Table 8 and Table 9.

Table 8 Mitigation Measures used in the Spreadsheet

Mitigation Measure	Risk Reduction Factor
None	1.00
Potential gas leaks obvious to members of public	0.80
Pipe located in safe area extremely unlikely to be damaged by vehicle	0.10
Wall thickness more than min required	0.67
Position protects against impact damage	0.10
Welded	0.50
Isolation valve	0.70
Supports in good condition	0.50
Localised corrosion	0.90
Above ground entry	0.70
Well ventilated area	0.90
Gas leakage survey	0.80
Gas alarms	0.90
Steel pipeline	0.20
Fire Protection applied to pipeline	0.10
Sprinkler system fitted	0.50
CCTV	0.70
Sleeved (e.g. GRP, pipe in pipe)	0.30
CP fitted & in good working order	0.20
Gas pipe labelled	0.80
Impact protection fitted	0.30
More than one means of escape	0.30
Asset not directly on means of escape	0.10

Table 9 Actions used in the Spreadsheet

Action	Risk Reduction Factor
No action required	1.00
No further mitigation identified	1.00
Install pipe supports	0.50
Repair pipe supports	0.50
Repair joints	0.50
Apply anaerobic sealant	0.50
Locate / Fit isolation valve	0.70
Inform owner of NG asset	0.90

Action	Risk Reduction Factor
Fit notice board	0.90
Replace pipeline	0.01
Repair corrosion & apply coating	0.10
Weekly leakage survey	0.60
Fortnightly leakage survey	0.80
Monthly leakage survey	0.90
Fit corrosion protection	0.20
Gas detection & alarm	0.80
Further investigation (survey more of asset)	0.90
Further investigation (determine corrosion level)	0.90
Install impact protection	0.30

7.6 Overall Risk Rating

7.6.1 Risk Assessment Rating

The risk score on the Risk assessment sheet is calculated as follows:

- Risk Rating – Impact Value x Likelihood Value x Mitigation Measure / Action (If Applicable)

The spreadsheet includes a colour coding mechanism whereby scores are either green, yellow or red depending on the risk rating calculated. The spreadsheet is set up so that there is a maximum value of 25 can be calculated by the spreadsheet.

The scores have been set to take into account the extreme worst case variant. The green, yellow and red bands are shown in the RA guidance tab of the spreadsheet.

8 CONCLUSIONS

A spreadsheet has been developed which allows data from high rise surveys to captured and recorded. Using this information, 'Priority' scores (previously referred to 'Risk Ranking' score) for buildings are generated and breakdown for individual assets given. If the value of this score is 210,000 or more, it is recommended a risk assessment is undertaken. If the score is less than 210,000 a re-survey should be undertaken in 5 years and if the score is less than 100,000 a re-survey should be undertaken in 10 years. It is recommended that these values be should be reassessed shortly after implementation and when more priority scores become available.

Priority scores for complex networks are currently being generated with incorporation of a number of additional threats / hazards identified by National Grid from an initial set of surveys. Additional comprehensive searches are scheduled to establish the number of assets likely to be present. Upon completion of these searches, initial surveys and generation of Priority scores, a review will be carried out to finalise the appropriate criterion for survey frequencies and the requirements for further risk assessment.

The data entered into the spreadsheet allows the survey information to be captured and analysed in detail. If a risk assessment is required, this information also allows an assessment of each asset to be undertaken so that appropriate risk reduction measures can be identified and / or implemented. This new two stage process will assist with the planning of maintenance activities to National Grid's assets within high rise and CDS buildings.

9 REFERENCES

[1] Report 2760, "An FN Calculation Method for Explosions in High Occupancy Buildings",

[2] Report 6402, "A risk assessment methodology for services to high rise buildings", A Phillips, 2003.

[3] Report 6334, "A qualitative risk assessment of riser arrays in high rise buildings for replacement prioritisation", DG Walker 2006

[4] Report 6444, "Demonstration of ALARP for Transco's Services to High Rise Domestic Properties", M Caulfield, A Phillips and DG Walker 2003

[5] Harlem Gas Explosion Report, NTSB Website, http://www.ntsb.gov/investigations/AccidentReports/Pages/PAR1501.aspx

APPENDIX A RISK RANKING CALCULATION (V3)

A.1 Risers

The scoring system is based on the subjective judgements of each measure identified. Each part of the chain of events leading to an explosion incident is considered separately.

In the equation below a number of factors are considered where different possible factors could result in different likelihoods of an explosion. These likelihood factors (L) are given values from one upwards, the larger the numerical value of an applied likelihood factor the greater the considered effect it would have on producing an explosion.

As well as likelihood factors, mitigation factors (M) have been identified. These are factors that tend to reduce the likelihood of the occurrences of an explosion producing fatalities. The mitigation factors are given values of up to one (i.e. 0 to 1), the lower the value the greater the assessed mitigating effect.

As well as factors associated with the building a factor is included to address the confidence surrounding the survey, principally the proportion of the riser that was surveyed.

The score for a riser in a high rise building is defined as:

$$SCORE = LR \times \{L_{SJ}\ M_{SJ} + \alpha\gamma/\beta\ L_{SC}\ M_{SC}\} \times L_{DM}\ M_{DM} \times L_F\ M_F \times L_{IG}\ M_{IG} \times L_H\ M_H \times S_C$$

where:

LR = Length of the riser pipe in metres

L_{SJ} = The likelihood of a spontaneous leak from a joint occurring. This failure of the joint could include fracture of screwed thread, weld failure, and any failure of a fitting.

M_{SJ} = Mitigation factors for reducing the likelihood of a spontaneous leak from a joint occurring.

L_{SC} = The likelihood of a spontaneous leak as a result of corrosion.

$\alpha\gamma/\beta$ = Weighting factor for the relative likelihood and consequence of corrosion hole relative to joint failure.

M_{SC} = Mitigation factors for reducing the likelihood of a spontaneous leak as a result of corrosion.

L_{DM} = The likelihood of not detecting and mitigating the leak.

M_{DM} = Mitigation factors for reducing the likelihood of not detecting and mitigating the leak

L_F = The likelihood of the gas leak being able to build-up to a flammable concentration.

M_F = Mitigation factors for reducing the likelihood of the gas leak building-up to a flammable concentration.

L_{IG} = The likelihood of an ignition of the flammable mixture occurring.

M_{IG} = Mitigation factors for reducing the likelihood of an ignition of the flammable mixture occurring.

L_H = The likelihood of a high consequence event occurring.

M_H = Mitigation factors for reducing the likelihood of a high consequence event occurring.

S_c = survey confidence

In essence the factors increasing the risk have values of one and above, whereas the mitigating risk parameters have values up to one. Overall, the higher the final score the greater the estimated risk for that building.

In this scoring system, relative weightings were initially given to the risk factors and mitigation measures identified above based upon engineering judgement. These weightings were then sense checked by National Grid as part of a sensitivity study and refined, where required, to produce the final weightings.

Where relevant the reasoning behind the relative weightings is presented in the notes to the tables presenting the relative weightings.

The values of α, β and γ are defined as 2.5, 4 and 1 respectively.

A.2 Calculation Coefficients for Internal Vertical Risers

A.2.1 Length of Riser

	Value assigned in scoring system
Total Length of riser (in m)	Value input Default = [Number of storeys x 4m] OR Height of building (in m)

A.2.2 Leaks from joints

The likelihood of a joint leak, L_{SJ}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of joint leaks	Value assigned in scoring system
Age of Riser	1 if the riser is less than 10 years old and 1.5 otherwise
Riser material	1 if steel, 6 if copper or unknown
Pipe diameter	1 if pipe diameter greater than 4" else 1.2
Riser Fixing to a recognised Standard	1 if riser fixing meets IGEM/G/5 standard, 2 otherwise. Not applicable =2.
Riser connection type	1 if welded, 2 if screwed, flanged or mixed. Not applicable =2.
Age of building	1 if over 10 years old else 1.1

Notes:

- It is assumed that newer buildings are slightly more prone to movement (initial settling) that may put stresses on the riser pipework.
- It is considered larger diameter pipes are less likely to spontaneous fail (fracture) at a joint. However, should such a failure occur, it is likely that the rate of gas escape would be greater for a larger pipe diameter, which in turn increases the likelihood of a production of a flammable gas mixture and for very large pipe diameters, increases the likelihood of a high consequence event.
- It is noted that copper pipes would be:
  - Susceptible to holes arising from electrical arcing.
  - More susceptible (relative to steel) to accidental (and deliberate) interference damage. More susceptible (relative to steel) to mechanical failure.
  - More susceptible (relative to steel) to damage during a fire (for example solder softens and melts by about 180ºC, which could then result in the separation of copper pipework).
  - It is also noted that the use of copper pipe for risers over 6-storeys high is clearly not recommended by various standards.

These features (excluding interference damage) are reflected in the weighting given to copper in the likelihood of spontaneous leaks.

There were no mitigation measures identified that would reduce the likelihood of joint leaks, M_{SJ}.

A.2.3 Leaks due to Corrosion

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The likelihood of a spontaneous leak due to corrosion, L_{SC}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Age of riser	1 if the riser is less than 10 years old, 1.5 if it is 10 to 20 years old and 2 otherwise.
Riser pipe material/ Corrosive Environment	If corrosive (damp/wet) environment present, then 8 if bare steel, 3 if tape wrapped steel, Painted steel, bituminous steel, yellow wrapped steel or galvanised steel, and 1 if copper or PE, otherwise 4. If environment is localised dampness, 1 if pipe is copper or PE else 3. If corrosive environment not present (always dry) then 1 if galvanised steel or copper, otherwise 1.2. If material is steel and pipe environment field is empty then issue a warning flag.
Corrosion Present on Riser	If material is steel: 1 if no corrosion, 2 surface rust, 10 if moderate, 25 if severe, 5 if unknown. Otherwise =1 If material is steel and field is empty then issue a warning flag.
Joints suitably wrapped	1 if all, 1.5 if some, 5 if none for steel pipes.
Pipe diameter as an estimate of wall thickness (in mm)	1 if pipe diameter is up to 3", 0.8 if more than 3", otherwise 1.
Repairs/replacement to any riser array for corrosion damage	If a single repair is visible on the riser then 6. If more than one repair then 10. If no visible repairs then 1. Default for missing data =2
Repairs required for steel pipes only	5 If corrosion protection repairs required, else 1
Internal leaks detected during leakage survey	1+[2 x number of leaks detected on the riser]
Entry of main to building when riser is connected to supply pipe.	2 If below ground entry or basement entry. Above ground entry =1. Default = 2

Notes

- In considering a riser material, the least protected category observed should be applied. For example were the riser constructed from PE coated lengths of steel pipe, but the connections were bare metal fittings, the overall riser should be treated as if it were bare steel.
- Repair/replacement is defined as repairs or replacement of part of a riser array not the renewal of the complete riser. If a riser had been renewed leaving existing riser arrays in place, the pipework within the building would be distinctly inhomogeneous and a more realistic risk ranking may be obtained by considering just the earlier pipework. However, in such a case engineering judgement would be required to assess the best way of evaluating the building.
- It is assumed that all risers within a building would be in similar environments. Hence any history of corrosion damage to one riser would be incorporated in the assessment of all risers within the building.
- It is assumed that the gas main typically enters the building at below ground elevation. If the pipe were to enter at above ground, it would be expected to reduce the likelihood of corrosion occurring near to the entry point.

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It is assumed that an identified requirement for repairs to the corrosion protection is not an indicator for immediate action.

Mitigation measures to reduce the likelihood of a spontaneous leak due to corrosion, M_{SC}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of corrosion leaks	Value assigned in scoring system
Internal leakage survey	0.8 if an internal leakage survey has been successfully undertaken with no leaks detected within the previous 2 years. Otherwise 1.
Visual Inspection of steel pipework	If severe corrosion not present, then 0.8 if visual inspection within last 2 years, 0.9 if within last 5 years. Otherwise 1.

A.2.4 Detection and Mitigation of Gas Leaks

The were no factors that were identified as mitigating the likelihood of a gas leak not being detected, L_{DM}.

Notes:

- LC21 does not identify the route of the riser within the building, for example within common areas such as stairwells or in dedicated service ducts.
- It would be considered more likely for a leak to be detected if the risers were located within a number of dispersed service ducts running through the individual flats rather than within a single central shaft.

Mitigation measures that could reduce the likelihood of a gas leak not being detected and mitigated, M_{DM}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of gas leaks not being detected and mitigated	Value assigned in scoring system
Public accessible Internal emergency shut off valve (SIV/NRIV/PIV) at base of risers	0.7 if present, otherwise 1
Riser sealed between floors	0.8 if sealed, 1 otherwise

Notes:

- It is considered that small leaks would be more readily detectable if the gas escape were not constantly being diluted and dispersed.

It is considered that if the route of the riser is sealed between floors, the ventilation to the leak would be reduced and possibly there would be the increased likelihood of producing a flammable mixture. However, this would be offset by enhanced dispersion throughout the storey and hence it would be more likely to be detected by an occupant through the odorant added to natural gas in the UK.

A.2.5 Flammable Build-up Resulting from Gas Leaks

In this section, those factors that increase the likelihood of a gas leak building up to flammable, L_F, have been identified and the effects assessed.

It should be noted that there is some overlap with the previous sections identifying the risk of leakage occurring without being detected and mitigated. In this section the main focus is the production of the flammable mixture itself, which would generally be promoted by larger gas escapes and escapes into small, poorly ventilated enclosures.

Factors that increase the likelihood of a flammable mixture building up	Value assigned in scoring system
Riser Material	1.1 if copper, otherwise 1
Presence of corrosion	If material is steel: 1 if no corrosion, 1.5 if surface rust, 2 if moderate, 6 if severe recorded, 2 if unknown Otherwise =1
Vertical riser sealed between floors	1.5 if sealed, otherwise 1

Notes:

- Widespread corrosion could indicate a potentially larger hole size (as well as likelihood of a leak occurring) and hence indicates a greater likelihood of a larger gas release.
- It is considered that an escape of gas from a fitting on a copper pipe could be slightly larger than would be obtained for a corrosion hole on a steel pipe. Hence a slight increase in the risk factor score is obtained for copper relative to steel.
- If the riser is sealed between floors then it is considered that this would reduce ventilation of any gas escape (including exchange of air with atmosphere outside building) and promote dispersion within one storey. These factors could increase the likelihood of producing a flammable mixture.

There were no additional mitigation measures identified that could reduce the likelihood of a flammable mixture building up, M_F.

A.2.6 Ignition of Gas Build-up following Gas Leaks

It is assumed that the most likely source of ignition would be associated with the electrical supplies to the building. However, it is possible that flammable mixtures could be ignited by other actions associated with the occupants.

The likelihood of a gas build-up being ignited, L_{IG}, is a function of the risk factors listed below. The effects of these risk factors have been assessed and are noted below.

It is noted that there could be some overlap with the earlier sections on leak detection and mitigation, and production of flammable mixtures. This section considers those factors primarily associated with the ignition source i.e. likelihood of an ignition source occurring within the flammable gas cloud. In this context it is noted that the larger the gas cloud the more likely an ignition source would be found inside the gas cloud, hence those factors promoting a large gas cloud would also increase the likelihood of ignition.

Factors that increase the likelihood of a gas build-up being ignited	Value assigned in scoring system
Vertical riser sealed between floors	1.2 if sealed, otherwise 1
Age of building	1 if less than 30 years, else 1.1

Notes:

- LC21 does not collect information on electricity supplies.
- It is considered that the close proximity of electricity supplies to the riser would increase the likelihood of any flammable mixture being produced by a gas escape coming into contact with an ignition source.

- If the riser is sealed between floors then it is considered that this would reduce ventilation of any gas escape (including exchange of air with atmosphere outside building) and promote dispersion within one storey. These factors could increase the likelihood of any flammable mixture produced coming into contact with an ignition source on the same storey as the gas leak.
- It is considered slightly more likely that a flammable gas cloud would come into contact with an ignition source within an older building relative to a new building (e.g. condition of electrical cables and equipment).

There were no additional mitigation measures identified that could reduce the likelihood of a gas build-up being ignited, M_{IG}.

A.2.7 High Consequence Events

The likelihood of a gas explosion resulting in a high consequence event comprising fatalities or multiple injuries due to the explosion, any subsequent fire or as a result of structural damage to the building, L_H, is a function of the risk factors listed below. The effects of these risks have been assessed and are noted below.

Factors that increase the likelihood of a high consequence event	Value assigned in scoring system
Riser Diameter	1 if less than 2.5" diameter, else 1.5.
Corrosion	If material is steel: severe corrosion =6, moderate =2 Otherwise= 1.
Vulnerable building	2 if system built modular and built before 1975 1.2 If system built modular and built since 1975 2 if brick/masonry and built since 1900 3 if brick/masonry and built before 1900. 1 if steel frame. If not determined is recorded for building types assume steel frame for over 6-storeys and brick built for up to and including 6-storeys.
Building identified as being prone to progressive collapse	20 if identified as being prone to progressive collapse, otherwise 1.
Entry of supply pipe into basement if connected to gas main	1.5 if riser enters through basement, otherwise 1. Default = 1.5.

Notes:

- It is noted that the key features of the high consequence event is the occurrence of a large explosion and/or fire and significant structural damage. In general, in order to get a large explosion, a large volume of a flammable natural gas-air mixture would be required which in turn would require a large release of gas. Hence those factors that would promote a large release of gas would increase the likelihood of a high consequence event.
- One factor that could lead to a large volumetric escape of gas would be the pressure of the gas in the pipework. However, the data collected by the site surveys would be limited to the pressure bands (e.g. Low pressure (LP) or medium pressure (MP) and thus differences in pressure within the LP range could not be used to differentiate the buildings.
- It is considered that in most cases the effects of the explosion would be limited to the flat or area in which the flammable natural gas–air mixture was ignited. In some cases it is considered that an explosion in a flat could cause some damage within the neighbouring flats on the same floor but would be unlikely to cause significant damage to the flats beneath and above.
- It is considered that in most cases an explosion in a common area such as a stairwell or landing or lift shaft would affect people in that area at the time, but it would not affect those in neighbouring flats. It is assumed that the number of people in the common areas is proportional

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to the number of inhabitants. However, LC21 does not collect information on the route of the riser within the building.

- It is considered that in many cases the volume and ventilation in a common area would be greater than for dwelling rooms, shafts and cavity walls within the building, in which case the likelihood of producing a flammable mixture from a gas escape would be less and hence the risk would be less. However, if the gas escape was in a region where ignition of the escaping gas prevented evacuation of the occupants, the risk from the subsequent fire would be considerably greater than if the riser were located elsewhere. The presence of an ECV on the riser would enable the gas supply to be readily isolated, thereby extinguishing the flames and facilitating the evacuation.
- It is considered that an explosion in a long duct/shaft could result in structural damage to the building that would be sufficient to affect neighbouring flats.
- In some cases the design of the building could be such that an explosion could produce a disproportionately large amount of structural damage, for example a modular panel construction. If such design issues were identified, the building would be classified as vulnerable. However, following Ronan Point (1968), measures were put in place to prevent disproportionate collapse of a building.
- It is noted that an explosion in the basement could cause significant damage to the building above. However, for this to occur it would require a release of natural gas into the basement. If there were no gas pipework inside the basement, this event would be considered highly unlikely.
- It is noted than a fire on a riser in a stairwell could hinder or prevent evacuation of the building with increased likelihood of smoke and fire related injuries. Isolating the supply of gas by the occupants or the emergency services using a publicly accessible SIV would reduce the likelihood of such injuries.

There were no additional mitigation measures identified that could reduce the likelihood of a gas explosion resulting in a high consequence event, M_H.

A.2.8 Survey Confidence

The risk ranking score obtained from the survey data has a level of confidence associated with the thoroughness of the survey. For example, some differentiation is needed between a survey that views 20% of the pipe and one that views 80%. This is expressed through the proportion of the riser surveyed and that two laterals were surveyed per riser. The effects of these have been assessed and are noted below.

Factors that affect confidence in the survey data	Value assigned in scoring system
Percentage of riser surveyed	1 if over 75%, 1.1 if 50 to 75%, 1.3 if 25 to 50%, 1.5 if under 25%.
	5 if pipe made of steel and corrosion categorised as "Unknown/NA"

It is noted that there is the potential for a surveyor to categorise a steel pipe as being of unknown condition. This is addressed through increasing the score for that particular pipe. Thus, if most pipes in the building were capable of being surveyed and categorised but one was not, a score would still be generated for the entire building.

A.3 External Risers

Only differences between internal and external risers are commented upon.

A.3.1 Length of Riser

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	Value assigned in scoring system
Total Length of riser (in m)	Value input Default = [Number of storeys 4m] OR Height of building (in m)

A.3.2 Leaks from Joints

The likelihood of a joint leak, L_{SJ}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of joint leaks	Value assigned in scoring system
Age of Riser	1 if the riser is less than 10 years old and 1.5 otherwise
Riser material	1 if steel or PE, 6 if copper or unknown.
Pipe diameter	1 if pipe diameter greater than 4" else 1.2
Riser Fixing to a recognised Standard	1 if riser fixing meets IGEM/G/5 standard, otherwise=2. N/A=2.
Riser connection type	1 if welded, 2 if screwed, welded or mixed. N/A =2.
Age of building	1 if over 10 years old else 1.1

There were no mitigation measures identified that would reduce the likelihood of joint leaks, M_{SJ}.

A.3.3 Leaks due to Corrosion

The likelihood of a spontaneous leak due to corrosion, L_{SC}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Age of riser	1 if the riser is less than 10 years old, 1.5 if it is 10 to 20 years old and 2 otherwise.
Riser pipe material/ Corrosive Environment	If corrosive (damp/wet) environment present, then 8 if bare steel, 3 if tape wrapped steel, Painted steel, bituminous steel, yellow wrapped steel or galvanised steel, and 1 if copper or PE, otherwise 4. If environment is localised dampness, 1 if pipe is copper or PE else 3. If corrosive environment not present (i.e. always dry) then 1 if galvanised steel PE or copper, otherwise 1.2. If material is steel and pipe environment field is empty then issue a warning flag.
Corrosion Present on Riser	If material is steel: 1 if no corrosion, 2 surface rust, 10 if moderate, 25 if severe, 5 if unknown. Otherwise=1. If material is steel and field is empty then issue a warning flag.
Joints suitably wrapped	1 if all, 1.5 if some, 5 if none.
Pipe diameter as an estimate of wall thickness (in mm)	1 if pipe diameter is up to 3", 0.8 if more than 3", otherwise 1.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Repairs/replacement to any riser array for corrosion damage	If a single repair is visible on the riser then 6. If more than one repair then 10. If no visible repairs then 1. Default for missing data =2
Repairs required to steel pipework	5 If corrosion protection repairs required, else 1
Leaks detected during leakage survey	1+[2 x number of leaks detected on the riser]

Mitigation measures to reduce the likelihood of a spontaneous leak due to corrosion, M_{SC}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of corrosion leaks	Value assigned in scoring system
Internal leakage survey	0.8 if an internal leakage survey has been successfully undertaken with no leaks detected within the previous 2 years, otherwise 1.
Visual Inspection of steel pipes	If severe corrosion not present, then 0.8 if visual inspection within last 2 years, 0.9 if within last 5 years, otherwise 1.

A.3.4 Detection and Mitigation of Gas Leaks

The were no factors that were identified as mitigating the likelihood of a gas leak not being detected, L_{DM}.

Notes:

- For an external riser it would be unlikely for the escape to be detected by a PRE unless it was a large leak or exceptionally still (low wind speed) conditions.

Mitigation measures that could reduce the likelihood of a gas leak not being detected and mitigated, M_{DM}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of gas leaks not being detected and mitigated	Value assigned in scoring system
Public accessible Internal emergency shut off valve (SIV/NRIV/PIV) at base of risers	0.7 if present, otherwise 1

A.3.5 Flammable Build-up Resulting from Gas Leaks

In this section, those factors that increase the likelihood of a gas leak building up to flammable, L_F, have been identified and the effects assessed.

It should be noted that there is some overlap with the previous sections identifying the risk of leakage occurring without being detected and mitigated. In this section the main focus is the production of the flammable mixture itself, which would generally be promoted by larger gas escapes and escapes into small, poorly ventilated enclosures.

Factors that increase the likelihood of a flammable mixture building up	Value assigned in scoring system
Riser Material	1.1 if copper, otherwise 1
Presence of corrosion on steel pipes	1 if no corrosion, 1.5 if surface rust, 2 if moderate, 6 if severe recorded, 2 if unknown

Additional mitigation measures that could reduce the likelihood of a flammable mixture building up, M_F, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a flammable mixture building up	Value assigned in scoring system
Riser located on outside of building	0.001 if on outside

A.3.6 Ignition of Gas Build-up following Gas Leaks

It is assumed that the most likely source of ignition would be associated with the electrical supplies to the building. However, it is possible that flammable mixtures could be ignited by other actions associated with the occupants.

The likelihood of a gas build-up being ignited, L_{IG}, is a function of the risk factors listed below. The effects of these risk factors have been assessed and are noted below.

It is noted that there could be some overlap with the earlier sections on leak detection and mitigation, and production of flammable mixtures. This section considers those factors primarily associated with the ignition source i.e. likelihood of an ignition source occurring within the flammable gas cloud. In this context it is noted that the larger the gas cloud the more likely an ignition source would be found inside the gas cloud, hence those factors promoting a large gas cloud would also increase the likelihood of ignition.

Factors that increase the likelihood of a gas build-up being ignited	Value assigned in scoring system
Age of building	1 if less than 30 years, else 1.1

Additional mitigation measures that could reduce the likelihood of a gas build-up being ignited, M_{IG}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a gas build-up being ignited	Value assigned in scoring system
External Riser	0.1 for the external riser

Notes:

- It is considered that the close proximity of electricity supplies to the riser would increase the likelihood of any flammable mixture being produced by a gas escape coming into contact with an ignition source. It is considered that an external gas riser would be highly unlikely to be close to electrical equipment and would be unlikely to be close to other ignition sources.

A.3.7 High Consequence Events

The likelihood of a gas explosion resulting in a high consequence event comprising fatalities or multiple injuries due to the explosion, any subsequent fire or as a result of structural damage to the building, L_H, is a function of the risk factors listed below. The effects of these risks have been assessed and are noted below.

Factors that increase the likelihood of a high consequence event	Value assigned in scoring system
Riser Diameter	1 if less than 2.5" diameter, else 1.5.

Factors that increase the likelihood of a high consequence event	Value assigned in scoring system
Corrosion of steel pipes	3 if severe corrosion, else 1.
Vulnerable building	2 if system built modular and built before 1975 1.2 If system built modular and built since 1975 2 if brick/masonry and built since 1900 3 if brick/masonry and built before 1900. 1 if steel frame If no value is recorded for building types assume steel frame for over 6-storeys and brick built for up to and including 6-storeys.
Building identified as being prone to progressive collapse	20 if identified as being prone to progressive collapse, otherwise 1.

Additional mitigation measures that could reduce the likelihood of a gas explosion resulting in a high consequence event, M_H, are listed below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a high consequence event	Value assigned in scoring system
External Riser	0.01 if external, else 1

Notes:

- It is unlikely that ignition of a gas cloud originating from an external riser would generate a significant pressure. Thus, would be unlikely to result in the structural collapse of building.
- It is noted that the key features of the high consequence event is the occurrence of a large explosion and/or fire and significant structural damage. In general, in order to get a large explosion, a large volume of a flammable natural gas-air mixture would be required which in turn would require a large release of gas. Hence those factors that would promote a large release of gas would increase the likelihood of a high consequence event.

A.3.8 Survey Confidence

The risk ranking score obtained from the survey data has a level of confidence associated with the thoroughness of the survey. For example, some differentiation is needed between a survey that views 20% of the pipe and one that views 80%. This is expressed through the proportion of the riser surveyed and that two laterals were surveyed per riser. The effects of these have been assessed and are noted below.

Factors that affect confidence in the survey data	Value assigned in scoring system
Percentage of riser surveyed	1 if over 75%, 1.1 if 50 to 75%, 1.3 if 25 to 50%, 1.5 if under 25%.
	5 if pipe made of steel and corrosion categorised as "Unknown/NA"

There is also the issue of how closely a survey undertaken a few years ago relates to the current condition of the riser. This is addressed in the section outlining mitigating measures for corrosion of the steel pipe.

A.4 Calculation Coefficients for Horizontal Risers

A.4.1 Length of riser

	Value assigned in scoring system
Total Length of riser (in m)	Value input Default = [Number of flats per storeys x 5m]

A.4.2 Leaks from joints

The likelihood of a joint leak, L_{SJ}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of joint leaks	Value assigned in scoring system
Age of Riser	1 if the riser is less than 10 years old and 1.5 otherwise
Riser material	1 if steel, 6 if copper
Pipe diameter	1 if pipe diameter greater than 4" else 1.2
Riser Fixing to a recognised Standard	1 if riser fixing meets IGEM G/5 standard, 2 otherwise. 2=N/A
Riser connection type for steel	1 if welded, 2 if screwed, flanged or mixed. 2=N/A
Age of building	1 if over 10 years old else 1.1

There were no mitigation measures identified that would reduce the likelihood of joint leaks, M_{SJ}.

A.4.3 Leaks due to Corrosion

The likelihood of a spontaneous leak due to corrosion, L_{SC}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Age of riser	1 if the riser is less than 10 years old, 1.5 if it is 10 to 20 years old and 2 otherwise. Use age of building as default.
Riser pipe material/ Corrosive Environment	If corrosive (damp/wet) environment present, then 8 if bare steel, 3 if tape wrapped steel, Painted steel, bituminous steel, yellow wrapped steel or galvanised steel, And 1 if copper or PE, otherwise 4. If environment is localised dampness, 1 if pipe is copper or PE else 3. If corrosive environment not present (i.e. always dry) then 1 if galvanised steel, copper or PE, otherwise 1.2. If material is steel and pipe environment field is empty then issue a warning flag.
Corrosion Present on Riser	If material is steel: 1 if no corrosion, 2 surface rust, 10 if moderate, 25 if severe, 5 if unknown. Otherwise 1 If material is steel and field is empty then issue a warning flag.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Joints suitably wrapped for steel.	1 if all, 1.5 if some, 5 if none.
Pipe diameter as an estimate of wall thickness (in mm)	1 if pipe diameter is up to 3", 0.8 if more than 3", otherwise 1.
Repairs/replacement to any riser array for corrosion damage	If a single repair is visible on the riser then 6. If more than one repair then 10. If no visible repairs then 1. Default for missing data =2
Leaks on riser detected during leakage survey	1+[2 x number of leaks detected on the riser]
Protection of riser pipework	If corrosion protection required then 3 if not required 1. Default = 2
Entry of main to building when connected to supply pipe	2 If below ground entry or basement entry. Above ground entry or N/A =1. Default = 2

Mitigation measures to reduce the likelihood of a spontaneous leak due to corrosion, M_{SC}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of corrosion leaks	Value assigned in scoring system
Internal leakage survey	0.8 if an internal leakage survey has been successfully undertaken with no leaks detected within the previous 2 years, otherwise 1.
Visual Inspection of steel pipe	If severe corrosion not present, then 0.8 if visual inspection within last 2 years, 0.9 if within last 5 years. Otherwise 1.

A.4.4 Detection and Mitigation of Gas Leaks

The were no factors that were identified as mitigating the likelihood of a gas leak not being detected, L_{DM}.

Mitigation measures that could reduce the likelihood of a gas leak not being detected and mitigated, M_{DM}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of gas leaks not being detected and mitigated	Value assigned in scoring system
Public accessible Internal emergency shut off valve (SIV/NRIV/PIV) at base of risers	0.7 if present, otherwise 1
Horizontal riser sealed between walls	0.8 if sealed, 1 otherwise

A.4.5 Flammable Build-up Resulting from Gas Leaks

In this section, those factors that increase the likelihood of a gas leak building up to flammable, L_F, have been identified and the effects assessed.

It should be noted that there is some overlap with the previous sections identifying the risk of leakage occurring without being detected and mitigated. In this section the main focus is the production of the

flammable mixture itself, which would generally be promoted by larger gas escapes and escapes into small, poorly ventilated enclosures.

Factors that increase the likelihood of a flammable mixture building up	Value assigned in scoring system
Riser Material	1.1 if copper, otherwise 1
Presence of corrosion on steel pipe	1 if no corrosion, 1.5 if surface, 2 if moderate, 6 if severe recorded, 2 if unknown
Horizontal riser sealed at walls	1.5 if sealed, otherwise 1

Additional mitigation measures that could reduce the likelihood of a flammable mixture building up, M_F, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a flammable mixture building up	Value assigned in scoring system
External Location	0.001 if external else 1

A.4.6 Ignition of Gas Build-up following Gas Leaks

It is assumed that the most likely source of ignition would be associated with the electrical supplies to the building. However, it is possible that flammable mixtures could be ignited by other actions associated with the occupants.

The likelihood of a gas build-up being ignited, L_{IG}, is a function of the risk factors listed below. The effects of these risk factors have been assessed and are noted below.

It is noted that there could be some overlap with the earlier sections on leak detection and mitigation, and production of flammable mixtures. This section considers those factors primarily associated with the ignition source i.e. likelihood of an ignition source occurring within the flammable gas cloud. In this context it is noted that the larger the gas cloud the more likely an ignition source would be found inside the gas cloud, hence those factors promoting a large gas cloud would also increase the likelihood of ignition.

Factors that increase the likelihood of a gas build-up being ignited	Value assigned in scoring system
Horizontal riser sealed at walls	1.2 if sealed, otherwise 1
Age of building	1 if less than 30 years, else 1.1

Additional mitigation measures that could reduce the likelihood of a gas build-up being ignited, M_{IG}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a gas build-up being ignited	Value assigned in scoring system
Horizontal riser could be external to the building	0.1 if External riser else 1.0

A.4.7 High Consequence Events

The likelihood of a gas explosion resulting in a high consequence event comprising fatalities or multiple injuries due to the explosion, any subsequent fire or as a result of structural damage to the building, L_H, is a function of the risk factors listed below. The effects of these risks have been assessed and are noted below.

Factors that increase the likelihood of a high consequence event	Value assigned in scoring system
Riser Diameter	1 if less than 2.5" diameter, else 1.5.
Corrosion	3 if severe corrosion, else 1.
Vulnerable building	2 if system built modular and built before 1975 1.2 If system built modular and built since 1975 2 if brick/masonry and built since 1900 3 if brick/masonry and built before 1900. 1 if steel frame If not determined is recorded for building types assume steel frame for over 6-storeys and brick built for up to and including 6-storeys.
Building identified as being prone to progressive collapse	20 if identified as being prone to progressive collapse, otherwise 1.

Notes:

- It is noted that an explosion in the basement could cause significant damage to the building above. However, for this to occur it would require a release of natural gas into the basement. If there were no gas pipework inside the basement, this event would be considered highly unlikely.
- A factor has been included for buildings identified by the building owner as being prone to progressive collapse. However, in practice it would be expected that such a notification would lead to immediate action being undertaken by National Grid.

Additional mitigation measures that could reduce the likelihood of a gas explosion resulting in a high consequence event, M_H, are listed below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a high consequence event	Value assigned in scoring system
External location	0.01 if External riser else 1

A.4.8 Survey Confidence

The risk ranking score obtained from the survey data has a level of confidence associated with the thoroughness of the survey. For example, some differentiation is needed between a survey that views 20% of the pipe and one that views 80%. This is expressed through the proportion of the riser surveyed and that two laterals were surveyed per riser. The effects of these have been assessed and are noted below.

Factors that affect confidence in the survey data	Value assigned in scoring system
Percentage of riser surveyed	1 if over 75%, 1.1 if 50 to 75%, 1.3 if 25 to 50%, 1.5 if under 25%.
	5 if pipe made of steel and corrosion categorised as "unknown/NA"

There is also the issue of how closely a survey undertaken a few years ago relates to the current condition of the riser. This is addressed in the section outlining mitigating measures for corrosion of the steel pipe.

A.5 Calculation Coefficients Used for Laterals

The scoring system for each individual lateral is similar to that used for the risers and is based on the subjective judgements of each measure, identified. Each part of the chain of events leading to an explosion incident is considered separately.

A.5.1 Length of Lateral

	Value assigned in scoring system
Length of lateral (in m)	Value input

A.5.2 Leaks from joints

The likelihood of a joint leak, L_{SJ}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of joint leaks	Value assigned in scoring system
Lateral material	1 if steel, 2 if copper or PE If material is PE and lateral is internal then issue warning flag and default to "999999999 "
Pipe diameter	1 if pipe diameter greater than 4" else 1.2
Lateral connection type for steel	1 if welded, 2 if screwed, flange or mixed 2= unknown, N/A or not steel
Age of building	1 if under 10 years old else 1.1

There were no mitigation measures identified that would reduce the likelihood of joint leaks, M_{SJ}.

A.5.3 Leaks due to Corrosion

The likelihood of a spontaneous leak due to corrosion, L_{SC}, is a function of the risk factors listed below. The effect of these risks has been assessed and is noted below.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Age of riser	1 if the riser is less than 10 years old, 1.5 if it is 10 to 20 years old and 2 otherwise. Unknown =2
Lateral pipe material/ Corrosive Environment	If corrosive (damp/wet) environment present, then 8 if bare steel, 3 if tape wrapped steel, Painted steel, bituminous steel, yellow wrapped steel or galvanised steel, And 1 if copper or PE, otherwise 4. If environment is localised dampness, 1 if pipe is copper or PE else 3. If corrosive environment not present (i.e. always dry) then 1 if galvanised steel, copper or PE, otherwise 1.2. If material is steel and pipe environment field is empty then issue a warning flag.

Factors that increase the likelihood of corrosion leaks	Value assigned in scoring system
Corrosion Present on lateral	If material is steel: 1 if no corrosion, 2 surface rust, 10 if moderate, 25 if severe, 5 if unknown Otherwise 1 If material is steel and field is empty then issue a warning flag.
Pipe diameter as an estimate of wall thickness (in mm)	1 if pipe diameter is up to 3", 0.8 if more than 3", otherwise 1.
Repairs/replacement to any lateral for corrosion damage	If a single repairs/replacement for corrosion damage has already been undertaken on the lateral then 6. If more than repair/replacement then 10. If no indication and/or record of any repairs then 1.
Repairs required	3 If corrosion protection repairs required, else 1
Internal leaks detected during leakage survey	1+[2 x number of leaks detected on the lateral]

Mitigation measures to reduce the likelihood of a spontaneous leak due to corrosion, M_{SC}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of corrosion leaks	Value assigned in scoring system
Internal leakage survey	0.8 if an internal leakage survey has been successfully undertaken with no leaks detected within the previous 2 years. Otherwise 1.
Visual Inspection of steel pipe	If severe corrosion not present, then 0.8 if visual inspection within last 2 years, 0.9 if within last 5 years. Otherwise 1.

A.5.4 Detection and Mitigation of Gas Leaks

The were no factors that were identified as mitigating the likelihood of a gas leak not being detected, L_{DM}.

The were no mitigation measures identified that could reduce the likelihood of a gas leak not being detected and mitigated, M_{DM}.

A.5.5 Flammable Build-up Resulting from Gas Leaks

In this section, those factors that increase the likelihood of a gas leak building up to flammable, L_F, have been identified and the effects assessed.

It should be noted that there is some overlap with the previous sections identifying the risk of leakage occurring without being detected and mitigated. In this section the main focus is the production of the flammable mixture itself, which would generally be promoted by larger gas escapes and escapes into small, poorly ventilated enclosures.

Factors that increase the likelihood of a flammable mixture building up	Value assigned in scoring system
Lateral Material	1.1 if copper, otherwise 1
Presence of corrosion on steel pipe	1 if no corrosion, 1.5 if surface rust, 2 if moderate, 6 if severe recorded, 2 if unknown.

Additional mitigation measures that could reduce the likelihood of a flammable mixture building up, M_F, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a flammable mixture building up	Value assigned in scoring system
Internal/external	0.001 if external, else 1

A.5.6 Ignition of Gas Build-up following Gas Leaks

Factors that increase the likelihood of a gas build-up being ignited	Value assigned in scoring system
Age of building	1 if less than 30 years, else 1.1

Additional mitigation measures that could reduce the likelihood of a gas build-up being ignited, M_{IG}, are given below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a gas build-up being ignited	Value assigned in scoring system
Internal/external location	0.1 if external else 1 for internal

A.5.7 High Consequence Events

The likelihood of a gas explosion resulting in a high consequence event comprising fatalities or multiple injuries due to the explosion, any subsequent fire or as a result of structural damage to the building, L_H, is a function of the risk factors listed below. The effects of these risks have been assessed and are noted below.

Factors that increase the likelihood of a high consequence event	Value assigned in scoring system
Lateral Diameter	1 if less than 2.5" diameter, else 1.5.
Corrosion	3 if severe corrosion, else 1.
Vulnerable building	2 if system built modular and built before 1975 1.2 If system built modular and built since 1975 2 if brick/masonry and built since 1900 3 if brick/masonry and built before 1900. 1 if steel frame If not determined is recorded for building types assume steel frame for over 6-storeys and brick built for up to and including 6-storeys.
Building identified as being prone to progressive collapse	20 if identified as being prone to progressive collapse, otherwise 1.
Lateral pipe in basement	3 if an internal lateral runs through basement, otherwise 1.

Additional mitigation measures that could reduce the likelihood of a gas explosion resulting in a high consequence event, M_H, are listed below. The effects of these measures have been assessed and are noted below.

Mitigation measures to reduce the likelihood of a high consequence event	Value assigned in scoring system
Internal/external	0.01 if external, else 1

A.5.8 Survey Confidence

Factors that affect confidence in the survey data	Value assigned in scoring system
Percentage of lateral surveyed	1 if over 75%, 1.1 if 50 to 75%, 1.3 if 25 to 50%, 1.5 if under 25%.

Notes:

Because stub laterals can be included within length of riser pipe and lateral surveys tend to be batched together, a simple proportion by number of the laterals cannot be used.

A.6 Calculation Factors for Supply Pipe

It is considered likely that in many cases there are no records for the supply pipe directly connected to the building, hence where relevant default values are indicated in the scoring tables.

Factors that indicate likelihood of escape from supply pipe into the building	Value assigned in scoring system
Length of pipe (m)	Nominal length of 10m used in the model
Pipe environment	Assumed permanently buried, hence 20 used for all pipes
Condition of main entering the building	If there is a MRPS score for main entering the building below 60 x 10^{-6} then score 1, above =2. If no MRPS score for pipe entering building then 2.
Age of supply pipe (time from mainlaying or integrity inspection)	1 if the supply pipe is less than 10 years old, 1.5 if it is 10 to 40 years old and 5 otherwise.
Condition of supply pipe main	If supply pipe main is: Well wrapped with metal beneath in pristine condition =0.1 Wrapped with no corrosion on metal beneath=0.3 Wrapped with superficial corrosion beneath = 0.5 Not wrapped, no visible corrosion = 0.7 Not wrapped superficial rust =1 Unknown =2 Moderate corrosion =10 Severe corrosion = 25
Material of supply pipe	0.1 if PE (basement, below ground or unknown entry) 0.01 if PE supply pipe has an aboveground/no entry. 1 if steel, cast iron (including spun cast iron) or ductile iron or unknown

Factors that indicate likelihood of escape from supply pipe into the building	Value assigned in scoring system
Pipe diameter as an estimate of wall thickness (in mm)	1 if pipe diameter is up to 3", 0.8 if more than 3". Default diameter is up to 3", i.e. 1.
Ground coverage outside building	Sealed surface = 3 Grass/open ground =1 Mixed sealed and open =2 Unknown = 2
Leaks detected on perimeter survey	1+[2 x number of leaks detected during perimeter survey]

Notes:

- To account for the length of supply pipe leading to the building being buried (essentially permanently located within a wet damp environment) the nominal length of pipe (10m) is multiplied by 20.
- For PE pipes it is assumed that there is 1 m tail on the PE pipe where the supply pipe/main enters the building, hence factor reduced by 10 if PE without above ground entry. If a PE main has an above ground entry, it is assumed that there is no significant length of buried steel and the factor is reduced by 100.
- It is recognised that in most cases a date of main laying will not be known for a steel supply pipe. In which case a date of confirmation that the pipe is in good condition may be used instead.
- It is possible that during the site survey, or more likely during an integrity inspection, a visual examination may be made of the supply pipe. Thus, a parameter has been included to allow the condition of the supply pipe to included.
- The likelihood of a corrosion failure of a buried distribution pipe leading to gas entering a nearby building is considered to be dependent on the pressure inside the pipe.
- Medium Pressure natural gas in the distribution network immediately upstream of the high rise flats could increase the risk relative to low pressure pipework through the possibility of failure of the pressure reduction system associated with the building. Such a failure of the pressure reduction system could have an impact in terms of
  - Carbon monoxide production through fuel rich combustion.
  - Sudden change in flame size for any appliances operating at the time of pressure reduction failure.
  - Change in pressure within riser may affect integrity of the riser pipework, possibly initiating a leak.
  - Change in pressure within meter area and installation pipework may affect integrity of this pipework.
  - Passage of gas through control valves on appliances to atmosphere, for example on cooker burners.

It would be expected that any hazard would involve failure of pressure control rather than loss of containment from pipework. It would not be expected that this would feed into pipe maintenance, repair, replacement and inspection issues.

Factors that mitigate likelihood of escape from supply pipe into the building	Value assigned in scoring system
Cathodic Protection system present	0.8 if confirmed present else 1 0.6 if currently working 0.4 if currently working in good condition

Factors that mitigate likelihood of escape from supply pipe into the building	Value assigned in scoring system
Perimeter leakage test	0.8 if a perimeter leakage test has been successfully undertaken with no leaks detected within the previous 2 years, otherwise 1.

Assume that:

- If Cathodic Protection present it has provided some protection from corrosion for the supply pipe.
- If Cathodic Protection is currently working it has provided some protection from corrosion for the supply pipe over the full lifetime of the supply pipe.

It is considered that the factors outlined in the following table increase the likelihood and consequences of an explosion following an escape of gas from the supply pipe to the building. For a significant escape from the pipe supplying the building many of the factors leading to a hazardous scenario will be very similar for all the buildings being considered. Only those factors where data are collected on the survey form and could indicate some differentiation between the buildings are included below.

Factors that increase likelihood of explosion and high consequence event following escape from supply pipe to the building	Value assigned in scoring system
Presence of cellar/basement	3 if cellar /basement area present, 1 if no cellar/basement
Entry of supply into building	1 if Above ground/no entry 2 if basement or below ground entry or unknown.
Vulnerable building	2 if system built modular and built before 1975 1.2 If system built modular and built since 1975 2 if brick/masonry and built since 1900 3 if brick/masonry and built before 1900. 1 if steel frame If not determined is recorded for building types assume steel frame for over 6-storeys and brick built for up to and including 6-storeys.
Building identified as being prone to progressive collapse	20 if identified as being prone to progressive collapse, otherwise 1.
Supply pipe immediately upstream of the building	1 if LP, 10 if MP

Notes:

- Whilst the pressure in the risers inside the building should be LP, a supply pipe pressure factor is included to account for the possibility that MP supplies are brought to the building line before being regulated down to LP prior to entering the building.

APPENDIX B GUIDE TO USING THE RISK ASSESSMENT SPREADSHEET

B.1 General guidance

1. The spreadsheet is locked, with inputs controlled quite tightly. Do not attempt to delete any rows, columns or cells.
2. Fill in as much information as possible.
3. Any cells formatted as below **must** be filled in. **You will not be able to complete the risk assessment without filling in all these cells.**

B.2 Data entry chronology

The spreadsheet should be filled in the following order:

1. Fill in the building information tab
2. Select the Supply Pipe information tab enter information for each supply pipe (see Section B.3.2)
3. Select the Riser Information tab and enter information for each riser (see Section B.3.3)
4. Using the button on the Riser Information tab, upload the ESRI diagram for the building, plus any photos relevant to the assessment (see Section B.3.4)
5. Select the Lateral Information tab and enter information for laterals surveyed. Note the form is designed for laterals to be grouped. (see Section B.3.5)
6. Select the IGEM Compliance tab and answer the questions, providing further details when prompted. (see Section B.3.6)
7. Select the Input Summary tab. Report any *Immediate Action Notes* and record Key Action Points as necessary.
8. Finalise the inputs using the button in the Input Summary tab. If any data is missing, you will not be able to finalise until the data is filled in.
    - **Upon finalising inputs, you will not be able to edit them. Ensure they are correct. Editing will be locked after finalising, and even if this is bypassed, scores will not update to adjust for editing post-finalisation.**
9. Select the RA tab and enter information on assets present (see Section B.4)
10. Select the RA summary tab and enter information (see Section B.4.1)
11. Finalise the spreadsheet. You will be prompted for a new filename to save the spreadsheet. More information about the finalisation process is below in Section B.4.1

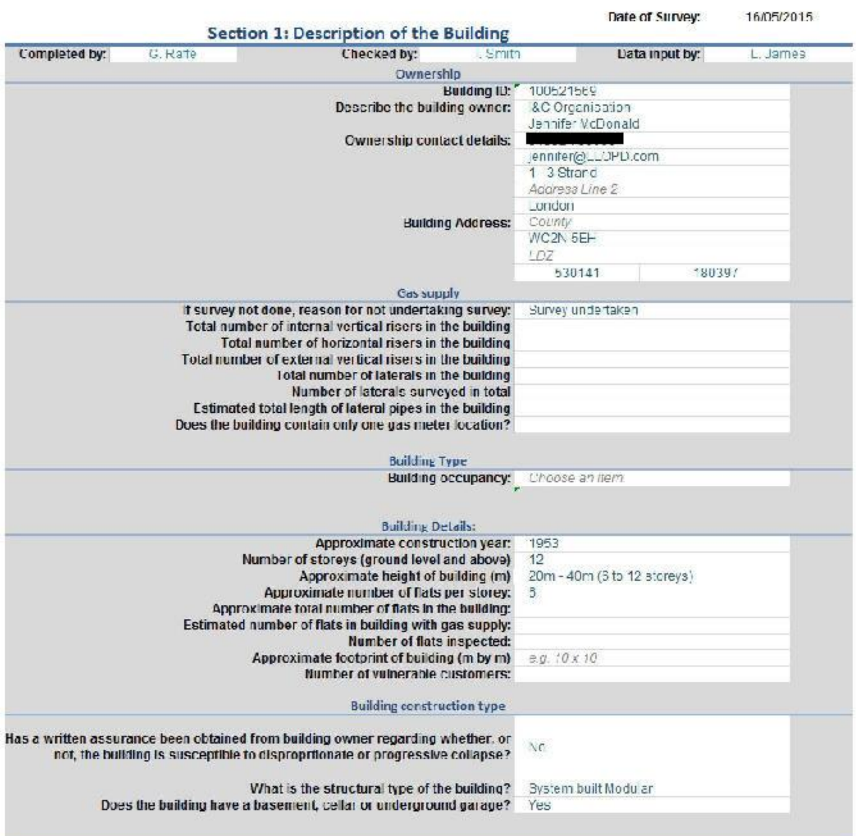
B.3 Data Entry (Stage 1)

B.3.1 Building Information

An example of the building information sheet is shown below.

Where possible drop downs have been provided and automatic calculations have been included:

- Approximate height of building
- Approximate number of flats in the building



Date of Survey: 16/05/2015

Section 1: Description of the Building

Completed by: G. Rafe | Checked by: . Smith | Data input by: L. James

Ownership	
Building ID:	100521569
Describe the building owner:	&C Organisation
Ownership contact details:	Jennifer McDonald
	[redacted]
	jennifer@LLOPD.com
Building Address:	1 3 Strand
	Address Line 2
	London
	County
	WC2N 5EH
	LDZ
	530141 / 180397
Gas supply	
If survey not done, reason for not undertaking survey:	Survey undertaken
Total number of internal vertical risers in the building	
Total number of horizontal risers in the building	
Total number of external vertical risers in the building	
Total number of laterals in the building	
Number of laterals surveyed in total	
Estimated total length of lateral pipes in the building	
Does the building contain only one gas meter location?	
Building Type	
Building occupancy:	Choose an item
Building Details:	
Approximate construction year:	1953
Number of storeys (ground level and above)	12
Approximate height of building (m)	20m - 40m (6 to 12 storeys)
Approximate number of flats per storey:	5
Approximate total number of flats in the building:	
Estimated number of flats in building with gas supply:	
Number of flats inspected:	
Approximate footprint of building (m by m)	e.g. 10 x 10
Number of vulnerable customers:	
Building construction type	
Has a written assurance been obtained from building owner regarding whether, or not, the building is susceptible to disproportionate or progressive collapse?	No
What is the structural type of the building?	System built Modular
Does the building have a basement, cellar or underground garage?	Yes

When no survey is undertaken:

- If for any reason no survey is undertaken, select the most appropriate option from the drop down.
- Provide any further information and any actions taken to schedule a resurvey on the Summary sheet.

Data-specific information:

- The table below shows guidance on specific inputs.

Data Item	Information about inputs
Construction Year	The year assessed in the Priority calculation, depend upon whether the building was built before/after 1900 for masonry buildings and 1975 for concrete/steel framed buildings
Obtaining Written Assurance	This is most commonly entered as unknown and is not critical for the calculation of the priority score.

B.3.2 Supply Pipe Information

- Input the number of supply pipes (maximum 20)

No of gas supply pipes connected to property:

  - *The spreadsheet will automatically adjust the table appropriately*

- Fill in as much of the table as possible for each supply pipe.

Column-specific information:

- The table below shows guidance on specific inputs.

Column Heading		Information about inputs
Reference		Automatically filled in - do not change.
ID		Mains ID, where present.
Material		Material of supply pipe - options include Steel, Cast Iron, Ductile Iron, PE and Unknown
Diameter	*(inches)*	Diameter of pipe in inches.
Operating Pressure		Pipe operating pressure - LP or MP.
Year main was laid		If this is unknown, enter as 0.
Ground coverage		
MPRS Risk Score		
Cathodic Protection?		Presence of cathodic protection on the supply pipe
Entry point		Select either above ground entry, below ground entry or basement entry.
Isolation valve (PIV/SIV)?		Presence of isolation valve along the supply pipe.
Isolation valve location		Record the Easting and Northing of the valve box.
External leakage survey undertaken?		
Number of leaks		
Leak location		
Pipe condition (corrosion)	Is pipe wrapped?	
	Condition	

B.3.3 Riser Information

- Select the most appropriate riser layout for the building

Riser layout:	Internal pipework (common area)

- Enter the number of risers (maximum 30).

Number of risers	

  - *The spreadsheet should automatically adjust the table appropriately*

- Fill in as much of the table as possible for each supply pipe.

Column-specific information:

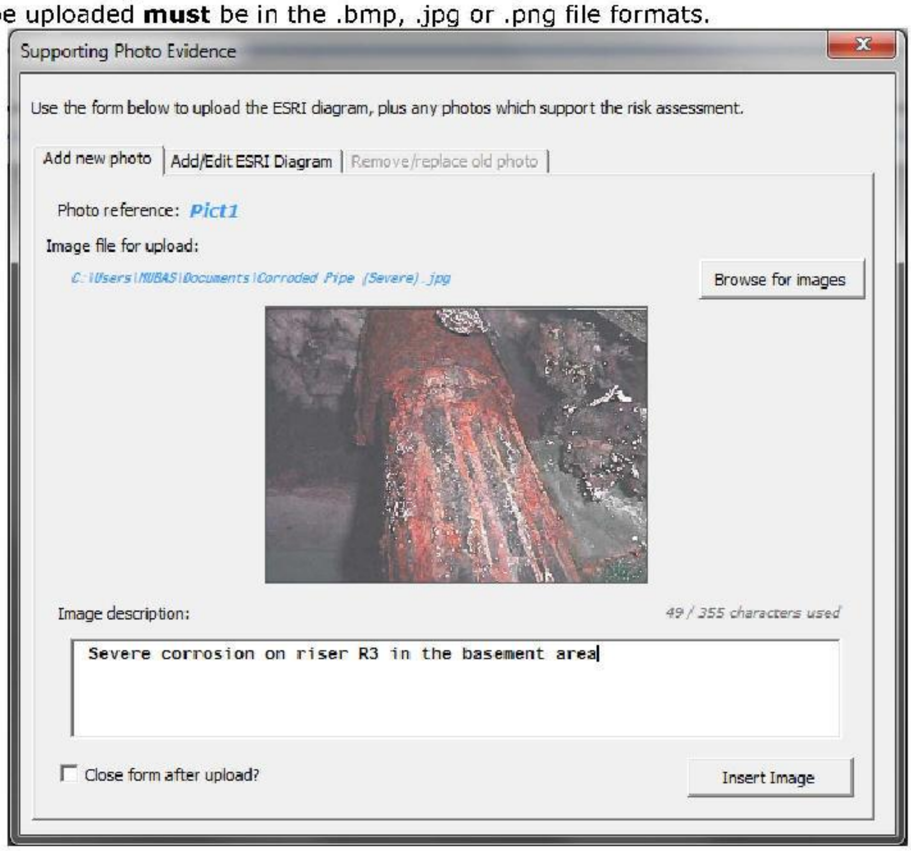
- The table below shows guidance on specific inputs.

Column Heading		Information about inputs
Riser reference		Automatically filled in - do not change.
Upstream Asset Ref		The reference (e.g. S1, R1 if horizontal riser) of the asset upstream of the riser
Material		Material of the riser - options are Bare/Coated/Painted Steel, PE, Copper & Other. If the riser is a mix of steel types, use the Bare Steel option.
% Visible		Percentage of the riser visually surveyed.
Pipe environment		
If riser is made of steel	Joint type	
	Protected?	
	Corrosion level	
	Corrosion Location	Free text field.
Isolation valve (PIV/SIV)?		Does the supply pipe to which the riser is connected to have an isolation valve. Information about IIVs, LIVs etc. can be recorded on IGEM compliance and summary sheet
Isolation valve location		Record the Easting and Northing of the valve box.
Number of repairs		Number of pre-existing repairs
Passes through solid floor/walls and is sealed?		
Condition of riser supports		Note this information has not been previously captured specifically for each riser. If no data is available select unknown.
Internal leakage survey undertaken?		
Gas leak information	# leaks	
	Gas leak location	
	Gas leak repaired?	

B.3.4 Supporting Photos

- Photos and the ESRI diagram can be uploaded using the button on the Riser Information tab.

- The below form will appear when the above button is pressed.
- Photos to be uploaded **must** be in the .bmp, .jpg or .png file formats.



- Uploaded images are stored in the Supporting Photos tab:

- To conserve the file size of the document, images are resized to have a height of 300 pixels. **If anything uploaded is of particular importance, keep a copy of the original.** This is strongly recommended for at least the ESRI diagram.
- Uploading photos isn't necessary, and is not required to finalise the risk assessment. However, once it is finalised, new photos cannot be uploaded.

B.3.5 Lateral Information

This form is designed for laterals to group based on similar properties to saved repetition.
For example, if ten laterals are more or less identical, you can input them as 1 lateral group with 10 laterals – this saves having to repeat the input of information 10 times.

- First enter the number of lateral groups (maximum 50).

  Number of lateral groups:

  - *The spreadsheet should automatically adjust the table appropriately*

- Fill in as much of the table as possible for each group of laterals.

Column-specific information:

- The table below shows guidance on specific inputs.

Column Heading		Information about inputs
Asset ref		Automatically filled in - do not change.
# of laterals in group		Number of laterals in each group - group laterals by similar specifications.
References of connected assets		Asset references of any assets connected to laterals in the group
Length of all laterals in group	*(m)*	TOTAL length of ALL laterals in group.
Pipe diameter	*(in)*	All laterals in the group should have same diameter and material.
Material		
% Visible		Percentage of the lateral group visually surveyed.
If lateral is made of steel	Joint type	
	Protected?	
	Corrosion level	
	Corrosion location	
Pipe environment		Level of Moisture of environments surrounding laterals. Should be same for all laterals in the group.
Isolation valve (PIV/SIV)?		Does the supply pipe to which the riser is connected to have an isolation valve. Information about IIVs, LIVs etc. can be recorded on IGEM compliance and summary sheet - should be same for all laterals in the group.
Isolation valve location		Record the Easting and Northing of the valve box.
Number of repairs		
Repairs fit for purpose?		
Gas leaks		
Gas leak location		
Gas leak repaired?		
Leakage survey undertaken?		

B.3.6 IGEM/G/5 Compliance

- Drop-down lists are provided for all questions.
- Wherever an answer is not compliant with IGEM/G/5, further details will be required.

FURTHER DETAILS REQUIRED ON 2 ITEMS

More information is required on the following questions:

Do all steel horizontal pipes have supports at least once every 3m?

Is any copper distribution pipework located on an escape route?

- Further information relating to specific questions is provided below.

Do all (horizontal/vertical) steel pipes have supports at least once every (3/2.5m)?

All pipes should be adequately supported.

For simplicity the initial site survey addresses support for horizontal and vertical steel pipes only through asking whether the observed unsupported lengths of vertical pipe exceed ~3m and the horizontal lengths exceed ~2.5m irrespective of pipe diameter.

Where the unsupported lengths exceed this threshold, it would be useful if the pipe diameter and estimated unsupported length could be noted in the comments section of the form.

Recommended maximum unsupported lengths of pipes are given in IGEM/G/5, as outlined below.

Nominal bore for steel / outside diameter for PE and stainless steel	Screwed steel - horizontal	Screwed steel - vertical	Welded steel – horizontal	Welded steel - vertical	External PE vertical
15/15	2.0	2.5	2.5	3.1	2.0
20/22	2.5	3.1	2.5	3.1	2.0
25/28	2.5	3.1	3.0	3.7	2.0
32/35	2.7	3.3	3.0	3.7	2.0
40/42	3.0	3.7	3.5	4.3	2.0
50	3.0	3.7	4.0	5.0	2.0
65	~	~	4.5	5.6	2.0
80	~		5.5	6.8	2.0
100	~		6.	7.5	2.0
150	~		7.0	8.7	2.0
200	~		8.5	10.6	2.0
250	~		9.0	11.2	2.0

Is the steel pipeline jointing method compliant with G/5?

Permissible joint types are presented in Section 7.4 of IGEM/G/5, the key features of which are summarised below.

Riser height or lateral length (m)	Steel pipe diameter up to 50mm (2")	Steel pipe diameter over 50mm (2")
Up to 20m	Screwed, End load resistant fitting Welded	Welded
Over 20 m and up to 40m	End load resistant fitting Welded	Welded
Over 40m	Welded	Welded

Is the network pipeline within a space that has adequate natural ventilation?

IGEM/G/5 defines ventilation requirements for new buildings and changes to existing gas pipe work. This survey is examining existing pipework. Hence, for the purposes of this survey:

The pipe is considered to have adequate ventilation if:

- The pipe is located on the outside of a building (e.g. an external riser).
- The pipe is located in a communal area such as a corridor, hallway or stairwell (e.g. external walkway, open staircase).
- The pipe is located in a duct or shaft that has ventilation openings to the outside atmosphere.
- An all-welded pipe is located in a shaft or duct that has ventilation openings into the building.

The pipe is considered not to have adequate ventilation if:

- The pipe is located in a room, duct, or void that does not have any ventilation openings to other rooms or to the atmosphere.

Using these definitions, a riser running vertically through a duct located in the kitchen (or other room) of a flat that would be considered not to have adequate ventilation if the only ventilation to the duct was the gaps around the access door to the duct.

Were there any exposed/unsleeved sections of PE pipe observed on the pipework?

Please note any sections of PE pipe that are exposed or unsleeved and provide further details in the comments boxes. This may be an issue that merits noting on the front page.

Are there any features of the building that are causing damage/deterioration of the NGG's assets?

During the site survey it is possible that features are noted where the condition of the building is causing damage or deterioration of National Grid distribution assets. In such a case the tick box should be ticked and a more detailed description given in one of the comments box, in Section 10. If the damage/deterioration is of high concern it should also be noted on the key action points box on the front page.

Examples of features would include:

- Pipework running through parts of the building that are excessively damp/wet
- Structure of building causing bending of (or putting strain on) the gas pipes

B.3.7 Input Summary

- The input summary will display key action points and warning flags, as well as showing scores.

Total scores:

- If any of these 'total score' cells show a highlighted *"Please fill out forms"* then data is missing.

Number of Risers	*Please fill out forms*
Total Riser Pipe Score	*Please fill out forms*

Warning flags:

- Warning flags are simply suggestions to check your data. For example, a warning flag appears if the number of internal vertical risers for which data has been entered in the riser tab does not match the number of internal vertical risers specified in the Building Description tab.

Immediate action notes:

- Items for immediate attention are flagged up where inputs show high-risk situations and should be addressed *immediately*.
- Any actions taken as a result of these should be described in the Key Action Points part.

Key Action Points
Please enter key action points

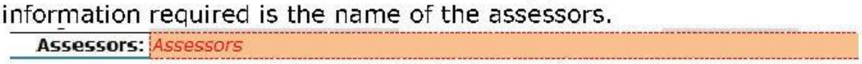
- If no survey has been undertaken, further information will be required.

Finalising inputs:

- Once all inputs are complete, click the "Finalise input" button.
- Before allowing the finalisation of inputs, the spreadsheet will perform a check for any missing data. If inputs are missing, the spreadsheet will indicate where inputs are required.
- Upon finalising, the inputs cannot be changed. If they were to be changed, scores calculated would not be overwritten.
- **If a survey has been undertaken** the user will be redirected to the Risk Assessment worksheet.
- **If a survey has not been undertaken** the user will be redirected to the RA summary worksheet.

B.4 RA Worksheet (Stage 2)

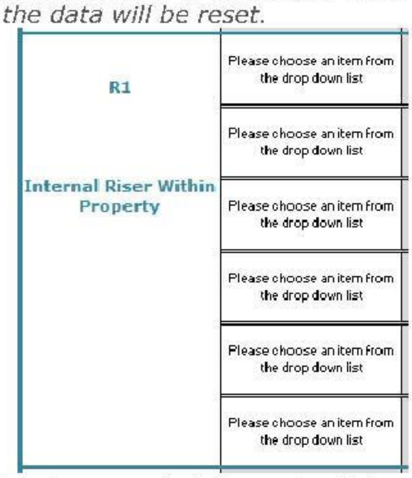
- The upper half of the RA worksheet will automatically pull data from the rest of the spreadsheet. The only information required is the name of the assessors.



- You can fill in data for six assets. Any unused asset slots will be deleted upon finalising the worksheet.

For each individual asset:

- First input the asset reference and pick the appropriate asset type from the drop down list.
  - *If you change the asset reference or asset type when other data for that asset has been filled in, the rest of the data will be reset.*



- Sequentially fill in the threat being recorded, the potential consequences of that threat and any relevant mitigation measures in place.
  - *The spreadsheet will automatically populate the risk matrix as soon as at the threat, consequence and (at least) one mitigation measure has been specified. If it is felt the value does not accurately represent the risk, these values can be overridden but the change must be recorded in the actions column.*
- If any actions are to be undertaken on the asset, record them. Pre-set actions are available in the drop down list.
  - *A new risk rating will be calculated based on the actions recorded.*
  - *Pre-set actions can be overridden but the new risk rating taking into account the effect of any actions will not reflect any non-pre-set values.*
- Capture information in this manner for each of the threats the asset faces (maximum 6 threats per asset)
- 6 threats do not have to be specified – any unused threat slots will be deleted upon finalising.

B.4.1 RA Summary

If no survey was undertaken:

- Indicate if a new survey has been scheduled and when it is due for.

Risk Assessment Summary

Total Building Priority Score 99,999,999

Immediate Action Notes

No survey done, please schedule one within 12 months.

Has a resurvey been scheduled? *Choose an item.*

No survey: Key information

Building owner has been contacted - a new survey has been scheduled for 24/08/2015

Next survey due: *Choose an item.*

- If a survey is not undertaken, a risk assessment cannot be undertaken and survey should be re-scheduled.

If a survey was undertaken:

- The fields in red require input before finalising the whole assessment.

Risk Assessment Summary

Number of Supply Pipes	1
Total Supply Pipe Score	138,240
Total Lateral Score	24
Number of Risers	6
Total Riser Pipe Score	3,374
Total Building Priority Score	141,638
Riser Contribution	2%

Immediate Action Notes

No actions for immediate attention

Have immediate attention factors been addressed? *Choose an item.*

Warning flags

CHECK: Values given for numbers of internal vertical and horizontal risers in Building Description sheet don't match that specified in Riser Information sheet

Key Action Points

Gas escape found on supply pipe and reported to National Grid. Exisiting Raychem Repair found on the pipework in the meter cupboard on the roof. Raychem Repair found in the boiler room on 6th floor but it is not clear if this is a National Grid asset. Other Notes: 4" Steel Pipework runs from the basement to the roof area and then connects to a commercial meter that provide gas to hot water boilers. There is also pipework dropping from the 6th floor to ECV/meter positions located in a common hallway. Only two flats using gas. Need to establish pipework belonging to National Grid.

INPUTS FINALISED

Estimated cost of replacement: -

Estimated cost of repairs: -

RA conclusions and actions

Please enter HAZID conclusions and actions

Next survey due: *Choose an item.*

Finalise Assessment

- This second finalising step will delete all unused rows in the RA worksheet, among other things. Once this is done, the risk assessment is complete and cannot be altered. Currently the file name is set to state the date of the survey and the Building ID.

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.