Public Safety – Application of Design Codes

Statement of Evidence

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Qualifications and Experience

1. My name is Jane Haswell and I am a Principal Consultant with Pipeline Integrity Engineers Ltd. My responsibilities comprise the technical delivery of projects concerned with the integrity and safety of pipeline systems.

2. I am a Chartered Engineer with a BSc in Mechanical Engineering, an MSc in Mathematical Modelling and Computer Simulation, and a PhD in Fracture Mechanics of Offshore Tubular Joints. I am a member of the Institution of Mechanical Engineers and the Institution of Gas Engineers & Managers. I have twenty eight years' experience in high pressure and pipeline engineering. I have been Chairman of the Institution of Gas Engineers and Mangers (IGEM) Panel on High Pressure Pipelines since 2001, and was responsible with this Panel for the drafting of Edition 5 of the standard IGEM/TD/1 for steel pipelines and associated installations for high pressure gas transmission, published in 2008. I have been a member of the BSI PSE/17 Committee since 2003. This Committee is responsible for the pipeline code PD 8010, and I was responsible as a member of the Onshore Working Group for drafting specific sections of PD 8010 pt 1 published in 2004. I am a joint author of the pipeline standards IGEM/TD/2 and PD 8010 pt 3, which cover the application of pipeline risk assessment to developments in the vicinity of high pressure pipelines.

3. Before joining Pipeline Integrity Engineers, I worked for 20 years in the UK gas Industry in a number of positions, ranging from stress analysis, fracture mechanics and defect assessment to management of specialist engineering teams responsible for technical support.

Knowledge of the Corrib Onshore Pipeline Project

4. In 2008 I carried out an assessment of the failure frequency due to third party damage for the Corrib Pipeline, and have provided consultancy support regarding pipeline codes and public safety since November 2009.

Scope of Evidence

5. In this statement I will explain

   i) The background to the development of the current pipeline codes,

   ii) The key principles applied by the codes to ensure public safety, including the process specified to ensure a pipeline is routed safely,

   iii) The codes which are applied to the Corrib pipeline,

   iv) How the Corrib pipeline complies with code requirements,

v) The safe distances associated with the pipeline, and the sensitivity which may be applied to these.

6. The Public Safety document is included in the Corrib Pipeline EIS, Volume 2, Book 6 of 6, Appendix Q6.2.

Background to the Development of Pipeline Codes Applied to the Corrib Pipeline and the Key Principles of These Codes

7. The principal codes applied to the Corrib pipeline are I.S. 328 and PD 8010 Part 1. These codes were developed from the ASME codes, the development of which commenced in the 1920s, when the design and construction of cross country gas and liquid transmission pipelines commenced in the United States.

8. In the 1960s, there was a UK national requirement to expand the gas transmission system. The Gas Council (which later became British Gas) examined the US pipeline code principles for application in the UK. In summary, the key principles identified were to:-

   - assess the infrastructure along the proposed route of the pipeline, and
   - limit the operating stress in areas of higher levels of infrastructure.

9. These principles were accepted, but were modified to ensure a higher standard of safety in the higher populated areas in the UK. The modifications involved:-

   - applying a building proximity distance based on the diameter and pressure of the pipeline, which defines the minimum required separation between the pipeline and existing normally occupied buildings which must be achieved, and within which future developments must be constrained,
   - reducing the pipeline operating stress in areas of higher population density.

10. A major research programme was initiated by British Gas, to evaluate the failure behaviour of and consequences of failure for high pressure gas pipelines. Similar research programmes were being undertaken in Europe (directed by the European Pipeline Research Group, EPRG) and in the USA (Battelle Memorial Institute, Pipeline Research Council International, PRCI). The results were shared, peer reviewed and published.

11. The key research results covered the following:-

    i) The thermal consequences at distances resulting from pipeline ruptures and leaks,

    ii) The design factor at which the pipeline failure mode is a leak, not a rupture,

    iii) Wall thickness requirements for resistance to damage which may result in through wall failure.

12. The results of the research programme were applied by British Gas as they became available, and were incorporated in full in the pipeline standard IGE/TD/1 Edition 2, which was published in 1984. The key requirements were, and remain largely, as follows:-

a. Calculate the building proximity distance (BPD) according to the pipe diameter and pressure. This distance defines the minimum safe distance between a pipeline operating at a design factor greater than 0.3 and less than or equal to 0.72 and normally occupied buildings. Determine the population density in a corridor 5 x BPD either side of the pipeline. Classify the area type as rural (R) where the population density is less than or equal to 2.5 persons per hectare, and suburban (S) where the population density exceeds this level.

   Note that the route corridor width was reduced to 4 x BPD in BS 8010, later editions of TD/1 and PD 8010 pt 1, but remains as 5 X BPD in I.S. 328.

b. The building proximity distance is defined as the distance at which the consequences of failure resulting from a rupture of the pipeline operating at a stress level of 72% of the yield stress of the pipeline material (ie a design factor of 0.72) are such that a person located at the building proximity distance and having access to an escape route or shelter will be subject to a risk levels equivalent to that for natural hazards ($1x10^{-6}$).

c. Where the area is classed as rural, the pipeline is routed to ensure there are no normally occupied buildings within the BPD.

d. Where the area is classed as suburban, the pipeline design is modified to ensure the operating stress does not exceed 30% of the yield stress of the pipeline material, ie a design factor of 0.3, to ensure that any failure will occur as a leak, not as a rupture.

e. Determine the building proximity distance for the pipeline in any suburban areas. The suburban area building proximity distances are based on the consequences of a leak, and are dependent upon the wall thickness of the pipelines as follows:-

   - Wall thickness $\leq$ 9.5mm, leak size equivalent to a 150mm diameter hole
   - Wall thickness > 9.5 and < 11.9mm, leak size is equivalent to a 75mm diameter hole.
   - Wall thickness $\geq$ 11.9mm, there are no consequence based requirements for the building proximity distance, as the likelihood of a through wall failure is minimal, so a minimum distance of 3m is required (for maintenance access).

13. The above code principles were adopted and applied in the Irish pipeline code I.S. 328, and the UK pipeline code BS 8010, which is now published as PD 8010 Part 1 2004.

14. A key objective of pipeline codes is to minimize safety risks to the public by minimising the likelihood of failure and limiting the consequences of failure by specifying minimum requirements for design, installation, testing and operation of the pipeline.

15. The codes minimise the likelihood of a pipeline failure by

   - Classifying the area around the pipeline in respect to population density, and applying a relevant design factor. The design factor defines the maximum working stress level in the pipeline.
   - Reducing the design factor to a maximum of 0.3 in areas where the population density exceeds 2.5 persons per hectare. This

controls the pipeline operating stress, which influences the tolerance to damage and ensures that rupture will not occur.

- Reducing the likelihood of material/construction defects through the use of material and inspection specifications that control material quality, fabrication standards, and pre commissioning testing requirements.
- Where the design factor exceeds 0.3, ensuring pipe wall fracture control through use of materials with a fracture toughness that is sufficiently high to control brittle initiation, prevent brittle fracture propagation and arrest ductile fracture propagation.
- Ensuring controls are in place to minimise degradation through the use of high quality coatings and the design, installation and maintenance of corrosion protection systems.
- And finally by ensuring the pipeline is resistant to impact damage caused by external interference at potentially vulnerable locations through use of increased pipe wall thickness and installation of pipeline protection.

16. The codes minimise the consequence of a pipeline failure by

    - As far as is practical, routing the pipeline through areas of minimum population and infrastructure.
    - Maintaining a minimum proximity distance between the pipeline and normally occupied buildings and infrastructure such as main roads as defined in I.S. 328.
    - Requiring a reduced design factor in populated areas to ensure that in the unlikely event of a pipeline failure, then the failure mode is a leak rather than a rupture.

17. The minimum distance to a normally occupied building can be derived using the results of the pipeline QRA where this is carried out.

18. The philosophy of the pipeline codes is to identify all potential damage mechanisms and to address these in the design, construction and operation of the pipeline to ensure failure does not occur. The codes require measures to be applied to protect the pipeline from 3rd party interference, but recognise that this type of damage is not fully within the control of the pipeline operator. The codes therefore specify minimum safe distances between the pipeline and normally occupied buildings, building proximity distances. These distances are based on the consequences which would arise from 3rd party damage, they are defined according to the worst possible failure which may occur and represent the distance at which a person is exposed to a risk level which is equivalent to that associated with other natural hazards.

19. The damage which can result from 3rd party damage is typically gouges, dents, cracks and combinations of these. This is the worst type of damage which can occur to a pipeline, and failure of this damage type is not dependant on whether the gas in the pipeline contains moisture or not. The BPDs defined by the codes therefore apply equally to both dry and wet gas conditions.

Design Standards & Codes Applied to the Corrib Pipeline

20. The design and code requirements are detailed in the Appendix Q3, and are addressed in the witness statement by John Gurden of J P Kenny. I will therefore only briefly discuss them in this witness statement.

21. As instructed by The Technical Advisory Group (TAG) on behalf of the Department of Communications, Energy and Natural Resources (DCENR), and in support of the Advantica recommendations the primary code critical to achieving a safe pipeline is I.S. EN 14161: Petroleum and Natural Gas Industries - Pipeline Transportation Systems

22. I.S. EN 14161 sets out the minimum requirements for pipeline design, and the introduction to the standard states that individual countries are allowed to apply their more detailed national requirements for public safety and the protection of the environment.

23. I.S. EN 14161 requirements are therefore supplemented by I.S. 328: Code of Practice for Gas Transmission Pipelines and Pipeline Installations, PD 8010 pt 1: Steel Pipeline on Land, and PD 8010 pt 3: Guide to the Application of Pipeline Risk Assessment to Proposed Developments in the Vicinity of High Pressure Natural Gas Pipelines.

24. These codes have similar principles in respect to design and routing requirements for pipelines, however while I.S.EN 14161 provides European base line requirements, I.S. 328 details the more stringent requirements to be adopted in Ireland, which include the application of the BPD, the area classification process and the hydrostatic test requirements.

25. I.S. 328 applies to dry natural gas, so does not address design and monitoring requirements for internal corrosion. These requirements are covered in PD 8010 pt 1. In addition, PD 8010 pt 1 requires that a safety evaluation involving a QRA is carried out for hazardous fluids classed as D or E. Natural gas is classed as D, so a full QRA is required by this code. PD 8010 Part 1 states that where a QRA is carried out, the individual risk results can be used to specify the width of the route corridor (ie distance to the risk level of 3×10^{-7} of receiving a dangerous dose either side of the pipeline, which is the outer zone defined in the Corrib pipeline QRA Report) and the minimum distance to occupied buildings (ie distance to the risk level of 1×10^{-5} of receiving a dangerous dose either side of the pipeline, which is the inner zone referred to the Corrib pipeline QRA Report).

26. The building proximity graphs in I.S. 328 and equations in PD 8010 pt 1 are consequence based, and relate to a generic risk of failure to a person at that distance which is equivalent to that for natural hazards.

Corrib Pipeline Compliance Assessment

27. The pipeline diameter and material have not changed from that proposed in 2009, i.e. external diameter 508mm (20” nominal diameter pipe), wall thickness 27.1mm with a corrosion allowance of 1mm and a manufacturing tolerance of 1mm and material grade X70. The design pressure therefore remains at 345 barg offshore and 144 barg onshore. This combination of diameter, wall thickness, material grade and pressure gives a design factor of 0.3.

28. The population density in the area 5 X BPD either side of the Corrib pipeline along the whole length of the pipeline is significantly below the maximum value of 2.5 persons per hectare allowed for a rural pipeline. The design factor of 0.3 at a design pressure of 144 barg was set in accordance with Advantica's recommendation that a cautious approach should be applied, and the pipeline should comply with the more onerous criteria for suburban area pipelines. The suburban area design criteria mean that rupture of the onshore pipeline section at a pressure of 144 barg will not occur. The wall thickness of 27.1mm provides a high resistance to through wall damage, so the likelihood of failure due to a leak is negligible.

29. However the following key changes have been made to the above:

- Routing beneath Sruwaddacon Bay, generally optimising the distance to houses on each side of the Bay, and
- Maximum Allowable Operating Pressures (MAOPs) have been established for the pipeline sections upstream and downstream of the LVI.

30. The principal change is the reduction of the maximum allowable operating pressure. The design factor remains below 0.3 so a pipeline rupture will not occur, and the high wall thickness ensures that the likelihood of through wall failures resulting in leaks is negligible.

31. I.S. 328 justifies routing a pipeline to a minimum distance of 3m to the nearest building in S areas where the pipeline wall thickness is 11.9mm or greater, on the basis that there is a negligible likelihood of a pipeline rupture at this low stress level, and a minimal likelihood of a through wall leak at wall thicknesses exceeding 11.9mm. At a design factor of 0.3 and wall thickness ≥ 11.9mm, the code does not require application of a proximity distance based on consequences, so a nominal right of way clearance only is required. A significant number of independent experimental and analytical studies have been conducted to establish this important design rule. Detailed results of such studies were published by British Gas, EPRG, the US Battelle Institute and the Pipelines Research Council International (PRCI).

Corrib Pipeline - Safe Distances and Their Sensitivity

32. As previously explained, the philosophy of the pipeline codes applied to the Corrib pipeline is to identify all potential damage mechanisms and to address these in the design, construction and operation of the pipeline to ensure failure does not occur. The codes require measures are applied to protect the pipeline from 3rd party interference, but recognise that this type of damage is not fully within the control of the pipeline operator. The application of safe distances between the pipeline and normally occupied buildings, (BPDs), are therefore required by the codes. These distances are consequence based, they are defined according to the worst possible failure which may occur and represent the distance at which a person is exposed to a risk level which is equivalent to that associated with other natural hazards, and apply to dry and wet gas.

33. The design of the Corrib pipeline is based on the code criteria applied to suburban pipelines, which ensure that:-

- Failure by rupture will not occur (ie the design factor does not exceed 0.3), and
- Resistance to through wall damage which may leak is maximised (based on wall thickness).

34. The safe distances which apply to the Corrib pipeline are those defined for suburban pipelines. As the wall thickness significantly exceeds 11.9mm, the resistance to through wall damage is very high and the codes do not require application of a consequence based distance, and define the minimum distance between the pipeline and any normally occupied building as 3m. In my experience, I am not aware of a through wall failure occurring in a pipeline with a wall thickness greater than 15mm.

35. In line with the cautious design strategy which has been applied to the Corrib pipeline, a maximum code based safety distance can be defined as the suburban BPD related to a leak from a 75mm hole.

36. The sensitivity of the safe distance from the pipeline in accordance with the codes is therefore as follows:-

    Pipeline Section downstream of LVI, MAOP = 100 barg:-

    minimum safe distance = 3m

    maximum safe distance = 13m (in line with cautious design strategy)

    Pipeline Section upstream of LVI, MAOP = 150 barg:-

    minimum safe distance = 3m

    maximum safe distance = 17m (in line with cautious design strategy)

    At the above maximum safe distances, a person standing at this distance will be subject to a risk level equivalent to that for other natural hazards.

Summary

37. The inherent level of safety of the currently proposed pipeline design approach continues to be significantly greater than the minimum requirements of the relevant codes in respect to the pipeline location relative to the nearest building.

38. The Corrib onshore pipeline originally had a safety design factor of 0.72 with a wall thickness determined by a design pressure of 345 barg.

39. Subsequently a design factor of 0.3 has been adopted based on a lower design pressure, as required by TAG.

40. The requirements of both I.S. 328 and PD 8010 for reduction of the design factor to 0.3 in suburban areas are based on published research which demonstrates that at the stress level at this design factor, in the event of a through wall failure, rupture will not occur.

41. This important design rule means that considerably reduced building proximity distances based on the consequences of leaks rather than ruptures are specified for pipelines having a design factor that is no greater than 0.3.

42. By retaining the design factor of 0.3 the Corrib onshore pipeline represents a higher level of safety than would normally be required by the code for the area classification through which the pipeline is routed, as the design factor is lower and the wall thickness is considerably greater than that required by the code in an area of low population density.

43. The individual risk levels for persons standing at the pipeline centreline as predicted in the QRA, see Appendix Q 6.4, are significantly lower than the level that enables risk-contour based building proximity distance criteria to be applied. This supports the design rule in both I.S.328 and PD 8010 pt 1, that pipelines can be safely routed to within 3m of buildings provided that the design factor does not exceed 0.3 and the pipeline wall thickness is greater than 11.9mm.

44. As suburban area design criteria have been cautiously applied to provide a greater level of safety, the minimum safe distance for the pipeline section downstream of the LVI where the MAOP is 100 barg, is 3m and the maximum safe distance is 13m. Upstream of the LVI where the MAOP is 150 barg, the minimum safe distance is 3m and the maximum safe distance is 17m.

45. All of the calculated building proximity distances are significantly less than the minimum nearest occupied building distance, taken as 234m.

46. The above assessment against the basic and long established code principles for design factor (stress level and therefore tolerance to damage/defects and control of the leak/rupture failure behaviour) will ensure that a full bore rupture will not occur, and the likelihood of a through wall defect resulting in a leak is minimal, and confirms the high safety factors and low risks associated with the Corrib pipeline.