PROPOSED CORRIB ONSHORE PIPELINE - Oral Hearing May 2009
QUANTIFIED RISK ASSESSMENT - Philip Crossthwaite, DNV.

QUALIFICATIONS AND EXPERIENCE

1. My name is Philip Crossthwaite. I am a Chief Specialist in DNV Energy (Det Norske Veritas Limited). DNV Energy is a leading professional service provider and our areas of expertise cover Asset Risk Management, Enterprise Risk Management, IT Risk Management, Safety, Health and Environmental Risk Management, Technology Qualification and Offshore Classification and Verification. I am in the Health, Safety and Environmental group based in the UK; worldwide this group comprises some 350 people.

2. I have a B. Sc and a Ph. D in Fuel Engineering. I am a Chartered Engineer and a Member of the Energy Institute (UK). I have been working in the field of health and safety for the past thirty three years following a few years working in combustion engineering. I was in the UK Health and Safety Executive (UKHSE), the UK safety regulator for 13 years, and for the remaining 20 years I have been a consultant (including 16 years with DNV). My experience includes auditing, inspection and risk assessment of various types of facilities. During the last 26 years I have carried out many quantified risk assessments (QRAs) of facilities that have fire, explosion and toxic hazards. During my time at the UKHSE I carried out QRAs on onshore gas and liquid pipelines and assisted in the development of the land use planning policies for the UK. I have carried out QRAs of onshore gas and liquid pipelines for many clients in many locations e.g. UK, various EU countries and China including export pipelines from LNG terminals and high pressure gas pipelines which form part of a country's gas transmission system.

3. I have worked on the Corrib project since 2003 preparing the quantified risk assessment for the terminal. My evidence today covers the QRA of the proposed onshore pipeline which is detailed in Appendix Q7 in the EIS.

SUMMARY

4. A quantified risk assessment has been carried out on the proposed pipeline to determine the predicted levels of risk at the houses in the vicinity of the pipeline and the landfall valve installation. The nearest existing occupied dwelling is 140m

from the pipeline route and at this distance the predicted level of individual risk is extremely low (negligible using terminology commonly used in QRAs). The nearest existing occupied dwelling is 246m from the landfall valve installation and at this distance the predicted level of individual risk is also negligible. Further the risk to the community, expressed as societal risk, is negligible, being several orders of magnitude below the criterion level contained in the risk supplement to the pipeline code BS PD 8010. The level of individual risk at the nearest existing occupied dwelling is lower than the lowest risk level specified by the Health and Safety Authority (HSA) for land use planning controls around sites subject to the European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations 2006 (S.I. No. 74 of 2006) (that is major hazard sites). The level of individual risk at the nearest existing occupied dwelling is also lower than that at some existing occupied dwellings in the vicinity of a high pressure gas pipeline constructed with thick wall to I.S. 328.

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5. The distance between a proposed pipeline and occupied dwellings is covered either by recommended minimum distances in the pipeline codes (termed the minimum building proximity distance, BPD) or by carrying out a QRA. The main pipeline code (ISEN 14161) does not contain recommended BPDs. The recommended BPD between the pipeline and normally occupied buildings according to the supplementary codes (I.S. 328 and BS PD 8010) would be 3-5m. The minimum distance between the proposed pipeline and an existing occupied dwelling is 140m. A QRA is not required if a proposed pipeline conforms to I.S. 328 or BS PD 8010. A QRA was carried out on the proposed pipeline to determine the levels of risk at existing occupied dwellings as the design pressure is outside the normal pressure envelope for the pipeline codes. A recently issued supplement to BS PD 8010 covers methods and criteria for pipeline QRAs in more detail than the main codes, and this has been used as a guide for the QRA.

THE QUANTIFIED RISK ASSESSMENT OF THE PROPOSED ONSHORE PIPELINE

6. A QRA is carried out to determine quantitatively (that is numerically) the risks from technological systems (such as pipelines transporting or plants processing flammable or toxic materials) so that decisions regarding the tolerability of the risk

and/or measures that could be taken to reduce the risk can be made. The methodology used by DNV followed the classical approach to QRAs which has been in use for process QRAs for over 30 years and is embodied in standards covering QRAs such as the above mentioned pipeline supplement and IEC-300-3-9 Part 3 Section 9: Application Guide - Risk Analysis of Technological Systems. The methodology comprises the following steps:

1. Define a representative set of scenarios that characterise the system being analysed.
2. Determine the frequencies, consequences and impact of these scenarios.
3. Combine these to give the cumulative risk from the scenarios and thereby the system.
4. Compare the risk predictions with suitable risk criteria.

THE SYSTEM

7. The system being analysed comprised:

- the pipeline from some 50m offshore to the landfall valve installation,
- the landfall valve installation itself and
- the pipeline from the landfall valve installation to the terminal.

To calculate the risks the method assumes that the system can develop a leak of gas which can then be ignited. The material being conveyed in the pipeline is a mixture of materials, primarily methane (93.7% by volume) with the balance comprising heavier hydrocarbons and inerts (Appendix Q1 in the EIS). This material is flammable but not toxic. In the event of ignition it can give rise to a thermal radiation (or heat) hazard and, in certain circumstances, an overpressure hazard. These two hazards are the main hazards posed by the gas in the pipeline and are addressed in the QRA.

8. To develop a representative set of scenarios we define several specific discrete hole sizes to characterise the full range of potential leak sizes. The choice of the hole sizes is usually dependent on the format of the information that is available on the likelihood of these failures. For the pipeline, the hole sizes used were:

- 12mm diameter (to represent pinholes or cracks up to 20mm)
- 31mm diameter (to represent holes from 20mm to the pipeline diameter), and

- Two holes of 454mm diameter (to represent a pipeline rupture).

The failure frequency data used for the landfall valve installation were from a different source than those used for the pipeline failures, but for simplicity the same hole sizes were used.

FREQUENCIES, CONSEQUENCES AND IMPACTS

9. The next step is to determine the frequencies, consequences and impact of the potential releases. Failure frequency data used for the pipeline were based on data from the European Gas Pipeline Incident Data Group. This dataset is the most appropriate dataset for QRAs of underground gas pipelines in Europe. The data are collated in terms of the following modes of failure:

- Third party interference.
- Construction defect/material failure.
- Corrosion.
- Ground movement.
- Hot-tap made by error.
- Other and unknown.

The frequencies used for all the modes of failure were taken from the 2005 report. A second quantified analysis which was carried out used a predictive methodology, which is specific to the proposed 27.1mm thick pipeline, to determine the frequency from third party impact based on potential dent and gouge damage. This predictive method to give the pipeline specific failure frequencies was carried out by Pipeline Integrity Engineers Ltd.; the full report is included as an Appendix in the DNV report (see Appendix Q7 of the EIS). The likelihood of failure due to ground movement was reduced to a negligible value compared with the generic value because the only area where this could be important was in the section of pipeline running through peat. The stone road was specifically designed to mitigate any issues associated with the instability of the peat.

10. The failure frequency data used for the landfall valve installation were based on data collected from experience on offshore platforms in the North Sea (generally known as OIR12 data). Although the conditions offshore are different from those onshore it has become normal practice over the last few years to use these data for QRAs of onshore equipment as the quality of the data is superior to the quality of currently available failure data which are specific to onshore equipment. As the data cover all failure modes, including failures when there is no or limited release of material, modification is required before they can be used in QRAs.

The actual values used in the analysis are taken from an interpretation carried out by BP in 2002 and recommended for use by BP operations when performing QRAs.

11. The failure mechanisms for pipelines laid underwater away from offshore platforms are similar to those for buried onshore pipelines (third party activity and corrosion are the main mechanisms), and overall failure frequencies for these pipelines are similar to those onshore. Consequently it is DNV practice to use the same frequencies for pipelines in the landfall area as those used for buried onshore pipelines.

12. Once the hole sizes in the system have been specified, the analysis of the consequences can be carried out. This involves the following;

- Determination of the release rate from the specified holes in the system
- Determination of the levels of heat that result from ignition of the gas
- Modelling of the impact or effects that the heat would have on people who are in the vicinity.

13 The pressure in the pipeline is sufficient to give a constant release rate from the two smaller hole sizes, and standard equations have been used to determine the release rates from these holes. For ruptures, the rate of release drops very rapidly from an initial rate, which is the same as that derived from the standard equations, to much lower rates as the pressure in the pipeline falls. The prediction for the rate of release from a pipeline with time is complex and a computer code developed at University College, London (Pipetech) was used for these predictions. DNV regard this code as being one of the best available to predict the release rate from a gas pipeline rupture.

14 In the event of ignition of the gas released from a hole in the pipeline, a flame will result. Ignited gas releases are typically modelled as either a 'jet flame' (where the release of gas is constant and a steady flame can stabilise) or a 'fireball' (which is a short duration unsteady event where a large quantity of gas is burnt in a short time). The releases from holes in the pipeline can be modelled adequately using the jet flame model in DNV's proprietary consequence modelling software. This is commercially available software that is used by more than 100

organisations worldwide including regulatory organisations (HSA and the UKHSE). The jet flame model has been validated against experimental data for methane (including release rates that are of similar magnitude to the release rates predicted for the hole sizes used in the analysis of the onshore pipeline).

15. Modelling the immediate ignition of a release of gas following a pipeline rupture is complex because of the dynamic nature and size of the release. The approach taken by DNV for this modelling was similar to that used by the UKHSE in that the first part of the release was modelled as a fireball, then the subsequent release was modelled as a jet flame.

16. Once the size of the fireball and jet flame have been determined, the heat that would be received by a person in the vicinity of the flame can be calculated. The effect of the heat is mainly dependent on the time for which the person is exposed to the heat, the location of the person with respect to the flame and whether the person is indoors or outdoors. If the level of heat received by the person is very high (i.e. the person is within or just outside the flame) it has to be assumed that the person would be fatally injured. As the distance between the flame and the person increases, the effects of the heat on the person become less significant and at very low levels of heat people will not be injured. Between these two locations people could be injured, possibly fatally, or escape without injury. The combination of the level of heat received and the duration of exposure (termed the dose) is related to the likelihood of fatality or injury and this was determined for people both indoors and outdoors at specific locations with respect to the release.

17. Under certain circumstances ignition of a flammable gas can give rise to overpressure as well as heat. Natural gas and methane, unless extremely cold, is lighter than air (the molecular weight of the gas in the pipeline is 17 compared with 29 for that of air) and so when the gas is released into the atmosphere, once the momentum has been lost, it will tend to rise above the ground as it mixes with air. In this respect the material being conveyed in the pipeline is different from many other flammable gases (such as propane and butane (LPG)) which are approximately twice as heavy as air. When they disperse the vapour/air cloud remains at low level. This is important, as when a flammable cloud is dispersing at low level it has the opportunity not only to contact ignition sources but also to drift into and accumulate within buildings and other structures or vegetation in the

vicinity. The combination of the flammable cloud and the environment into which the cloud disperses determines whether there is generation of overpressure, additionally to the generation of heat, on ignition. In the event of a release from the pipeline, the gas would mix quickly with air and the cloud would rise above the ground. The size of the flammable cloud at ground level is relatively small and experience shows that ignition of releases of natural gas from buried pipelines has only given rise to overpressure if the gas release is close to or within buildings. Consequently, as the proposed pipeline is a considerable distance away from buildings and comprises material that is similar in terms of combustion properties to natural gas, any release would not accumulate within a building or other environment which could cause overpressure, so ignition to give overpressure can be neglected. This is consistent with the approach used by the UKHSE for QRAs of natural gas transmission pipelines in the UK.

RISKS

18. The final part of the analysis involves the combination of the frequencies and the impacts to give risks. Risk predictions are typically presented in two forms: individual risk and societal risk.

19 Individual risk predictions are numerical and various formats are used. These are shown on the SLIDE. The normal format is shown in the centre of the SLIDE, in the column headed 'Frequency'. A risk of 1 x 10^{-6} per year means that there is a one in one million (10^{6}) chance (column 1) that a person who spends a year at that location will be fatally injured. This is also written as 1 cpm (chance per million) as shown in the third column. The risk plots in the EIS (Appendix Q) are shown in 'E format', as this is the format used by the computer programs. A risk of 1.00E-06 per year is the same as a risk of 1 x 10^{-6} per year. Similarly a risk of 1 x 10^{-9} per year is the same as 1.00E-09 per year, or 1 in a billion per year or 0.001 cpm. The SLIDE shows that as the risk goes from a value the top of the SLIDE to the bottom of the SLIDE, the risk is increasing. This is illustrated by the arrows at the sides of the SLIDE. The colours indicate that high risks should be avoided (red), green risks are typical of those that are considered to be tolerable and orange risks can be tolerated only if the risks cannot be reduced.

20. The individual risks have been determined at various locations with respect to the pipeline. The individual risk at the nearest existing occupied dwelling assuming

operation at the design pressure (144 bar) is 5 x 10^{-11} per year. Is is indicated on the SLIDE as being well below 1 x 10^{-9} per year. The risk at the nearest existing occupied dwelling to the landfall valve installation assuming operation at the design pressure (144 bar) is 1 x 10^{-7} per year. Other individual risk predictions are given in the EIS (Appendix Q7, Appendix IX).

21 The HSA has criteria for land use planning controls around sites subject to the European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations 2006 (S.I. No. 74 of 2006) (major hazard sites) and the siting of new major hazard sites. For the latter, the risk at the nearest residential type property should not be greater than 1 x 10^{-6} per year. Three risk zones are defined for land use planning in the vicinity of major hazard sites; the boundary of the outermost zone (i.e. that with the lowest risk) is set at 3 x 10^{-7} per year. These two levels of individual risk are indicated on the SLIDE.

22 Risks from everyday activities or occupational risks are often used to put technological risks into perspective. One of the highest occupational risks is that from agriculture, forestry and hunting (HSA category) which is approximately 1 x 10^{-4} per year and indicated on the SLIDE. The risks from construction are similar, but most other occupational risks are well below this level

23 The UKHSE has criteria for land use planning controls around both major hazard sites and pipelines. Pipelines are required to be designed and constructed to an industry code of practice (e.g. BS PD 8010), and HSE advises planning restrictions within a certain distance of the pipeline (based on risk). For thick wall pipelines the risk at the BPD is generally less than 1 x 10^{-6} per year, and this is always the case for pipelines with a wall thickness of 19.1mm or more. The risk at the boundary of the outermost zone for land use planning is set at 3 x 10^{-7} per year. A typical range is shown on the SLIDE.

24. A QRA is not required for high pressure gas transmission pipelines designed in accordance with I.S. 328. DNV has not carried out a QRA for the Pipeline to the West or any other high pressure gas pipeline in Ireland. The former has a design pressure of 85 bar and a diameter of 914 mm. In the sections of the pipeline that are constructed with heavy wall, the predicted frequency of a rupture is higher than that for the proposed Corrib pipeline. Further, the predicted consequences in the event of a rupture are greater than those calculated for the Corrib pipeline and the

distance to the nearest housing is less than the minimum distance to the nearest existing occupied dwelling to the Corrib pipeline. Hence, the predicted risk levels at some dwellings in the vicinity of this pipeline are higher than the predicted risk levels at the existing occupied dwellings from the proposed Corrib pipeline.

25. DNV would therefore interpret the predictions from the QRA that the level of individual risk from the proposed pipeline and landfall valve installation to people in the existing occupied dwellings is extremely low (or negligible using terminology commonly used in QRAs).

26. Societal risk is a measure of the risk due to accidents which may cause varying numbers of casualties. The predicted level of societal risk from the proposed pipeline to the existing occupied dwelling houses was also found to be extremely low (negligible) as it was several orders of magnitude below the criterion level proposed in the risk supplement to PD 8010. Examples of the societal risk predictions in graphical format are given in the EIS (Appendix Q7, Appendix IX).

SUMMARY

27. A quantified risk assessment has been carried out on the proposed pipeline to determine the predicted levels of risk at the houses in the vicinity of the pipeline and the landfall valve installation. The nearest existing occupied dwelling is 140m from the pipeline route and at this distance the predicted level of individual risk is extremely low (negligible using terminology commonly used in QRAs). The nearest existing occupied dwelling is 246m from the landfall valve installation and at this distance the predicted level of individual risk is also negligible. Further the risk to the community, expressed as societal risk is negligible, being several orders of magnitude below the criterion level contained in the risk supplement to the pipeline code BS PD 8010. The level of individual risk at the nearest existing occupied dwelling is lower than the lowest risk level specified by the HSA for land use planning controls around sites subject to the European Communities (Control of Major Accident Hazards Involving Dangerous Substances) Regulations 2006 (S.I. No. 74 of 2006) (that is major hazard sites). The level of individual risk at the nearest existing occupied dwelling is also lower than that at some existing occupied dwellings in the vicinity of a high pressure gas pipeline constructed with thick wall to I.S. 328.