Review of Shrinkage Calculations in Shrinkage Leakage Model – 30 June 2017

DNV GL has reviewed the following two documents and has addressed the concerns raised where evidence is available to either refute or accept the conclusions :-

- Energy UK Gas Retail Group Study into the effect of shrinkage on domestic customers, IC Consultants Ltd for Energy UK, October 2015

- Joint Gas Distribution Network (GDN) response to the Energy UK Gas Retail Group Study into the effect of shrinkage on domestic customers

Each report is considered in turn. The conclusions are listed and addressed individually. Where DNV GL believes there is insufficient technical expertise or evidence to address a conclusion, this is indicated.

Review of Energy UK Gas Retail Group Study into the effect of shrinkage on domestic customers

Conclusion 1
The model is most sensitive to

- the metallic length
- the leakage rate for the metal service connected to metal main
- the number of relays per km
- the leakage rates of polyethylene (PE) mains

Response 1

This is accepted by DNV GL.

Conclusion 2

There is evidence that a zero leakage rate (as assumed by the model) for polyethylene services is highly unlikely in practice (although this number is low).

Response 2

The measured leakage rate for PE services was not zero but was negligible. It was based on actual leakage measurements from a number of test sites. Although the leakage rate from the services was too small to quantify separately, the actual leakage from services is included within the PE mains leakage rate.

Conclusion 3

The sample-based approach from the 2002 study to generate the leakage factors is likely to generate a bias towards underestimation as the leakage rate distribution is skewed, with large amounts of leakage being caused by relatively few leaks in large systems; such leaks could be missed in small samples.

Response 3

DNV GL agrees that the leakage distribution is skewed but it also confirms that the tests which were carried out were on a reasonable sized sample, specifically designed to be stratified against the proportions of material in the system. All the sample sizes are larger than those in the comparative studies.

Conclusion 4

We have found that there are some important anomalies in the shrinkage model which are not consistent with theory; that some of the data are not in line with international estimates and some assumptions border on the optimistic. It has been over 12 years since the last calibration study and it would be reasonable to request another one, especially considering the intervening improvements in technology.

Response 4

The data are based upon the largest test sample carried out anywhere in the world. The original test programme (based upon a sample of 574 pipes) was carried out in 1992. The second test programme, carried out 10 years later (based on over 800 pipes) produced results which were similar to those carried out 10 years earlier and did not show signs of significant improvement or deterioration over the period. However, the proportion of metallic and PE mains has changed considerably over the period. In 1992, the number of tests carried out on PE pipes was disproportionately small compared to metallic. In the intervening period, the population of PE has grown, whilst the population of metallic mains has decreased. It would therefore be prudent to re-consider testing a sample of PE mains to consolidate the results for PE alone.

Conclusion 5

More evidence to justify the network composition assumptions should be made available to shippers and other stakeholders to generate more confidence in the SLM. We were not able to find evidence on network composition on the gas governance website.

Response 5

The GDNs have good records relating to the composition of networks by material and diameter.

Conclusion 6

The elapsed time means that knowledge of how the model was developed and the assumptions made and procedures for model maintenance are not as clear as they could be.
Note that the same model is used in each region/area.

Response 6

Some of the experts who developed the original sampling plans and analysis are still available and documentation on the original tests is also available. DNV GL is not aware how well the procedures for model maintenance are documented.

Conclusion 7

There is evidence from a review of actual international methane emission measurements in cities that reported leakage rates based on estimation models underestimate actual leakages. For example, a London study described in section 4.2 indicates that actual leakage rates could be up to three times higher.

Response 7

DNV GL understands the London study took airborne readings only. For readings to be detectable in the atmosphere, the original leak would be significantly higher than 'background leakage', or seepage from weeping joints etc, which were included in the NLT programme, therefore it is DNV GL's view that the sample of measurements taken is unrepresentative of the full range of leakage values and is likely to over-estimate the real level of leakage.

Conclusion 8

This will be of increasing concern as countries will be required to provide increasingly accurate greenhouse gas (GHG) emissions inventories. For example, DEFRA/DECC must provide such statistics to the European Commission and UNFCC.

Response 8

No response to be made from DNV GL.

Conclusion 9

- The Shrinkage Allowance and Environmental Emissions Incentive have had some effect on improved system pressure management which has had a moderate impact but may increasingly not deliver the desired effect.
- The HSE based IMRP (REPEX) process has potentially had a larger impact on shrinkage than the Ofgem shrinkage allowance and emissions based incentives, although both policies generate similar outcomes. Around 80% of the shrinkage reduction arises out of mains replacement.

Response 9

DNV GL has no response to make on the above conclusions.

Conclusion 10

The model assumptions around iGTs are leading to an underestimate of shrinkage: iGTs started off as a small part of the system but they are now quite substantial and efforts should be made to include them

properly in the estimation of shrinkage and to require the relevant reporting. There are around 1.5 million meter points and the actual shrinkage could constitute up to 2-5% of the current estimate, i.e. £1.4-3.5m. Furthermore, no figures are available for estimates of third party damage/interference; it may be expected that relatively higher amounts of excavation are taking place in iGT areas as they are areas of new development.

Response 10

DNV GL has no evidence to conclude that shrinkage from iGTs is different to that from the GDNs. It accepts that relatively higher amounts of excavation are taking place in areas of new development. However, external interference is usually detected immediately and rectified, so that, whilst they may result in gas loss, the loss is over a relatively short space of time. This is likely to be significantly smaller than levels of background leakage which may exist undetected for many years.

DNV GL does agree, however, that as CSEPs are now part of the overall distribution system, their contribution to leakage should be measured and considered as part of the overall shrinkage estimate.

Conclusion 11

The water industry equates leakage rate estimation with unaccounted for supply and bases it on actual measurements using on the balance between water entering the network and that consumed. A total/integrated flow method is used for the whole network and a “night-flow” method for smaller sub-networks.

Response 11

Previous studies by the gas industry have concluded that the significantly lower levels of leakage from the gas system are unable to be measured by a balance or night-flow method due to the inaccuracy of meters being potentially greater than the leakage being measured and the inability to find networks where night-time consumption is minimised.

Conclusion 12

The oil and gas production industry uses “age factors” to indicate that older equipment is expected to have higher leakage rates. This could be particularly relevant to AGIs and preheaters. It also applies temperature and pressure corrections which could be used to improve shrinkage estimates. Finally, it has developed a range of leak detection and measuring methods (e.g. IR detection, bagging) which might be exploited in distribution networks.

Response 12

DNV GL agrees that older equipment may have higher leakage rates. It also agrees that newer leak detection methods, available since the test in 2002, might be exploited should the industry decide to repeat some leakage tests.

Conclusion 13

The Netherlands survey their GDNs every 5 years, leading to good quality network composition data (less than 0.4% unknown). This is an example of best practice.

Response 13

The GDNs carry out a rolling 5-year programme to re-survey 20% of their system annually as part of the IMRP implementation.

Further comments

Conclusion 14

The report by IC Consultants states that,

"One can see from that Figure 8 and Figure 9 the dependence of the leakage rate for Pit cast mains versus diameter D is highly non-monotonic which contradicts physical laws (see section 3.2). We also note that the leakage rates for steel increase with diameter as expected, while they decrease with diameter for ductile which is somewhat unrealistic. The leakage rates for PE and spun cast do not depend on diameter at all, which is again not in accordance with permeation physics. All these inconsistencies are probably the result of limited samples size of materials and networks used in the tests and potentially inaccurate statistical methods applied for processing data."

Response 14

This statement is incorrect. It is correct to state there is very clear evidence that leak rate has strong relationship with diameter. This is the occurrence of leaks per km per year. There is no evidence to show that leakage (i.e. the level of gas loss from a pipe) is related to diameter. Fracture rate in particular shows a strong inverse relationship with diameter based upon beam strength. Once the pipe has fractured, gas loss will not be uniform around the circumference of the pipe so there is no reason to expect it to be proportional to diameter.

Conclusion 15

The report also states that
"There is another important assumption in the mains leakage. This relates to Medium Pressure (MP) Leakage (8% of leakage). The model assumptions state:
MP Leakage is estimated by applying the LP leakage rates at 30mbar to the MP mains asset profile. The rationale for this is that the number of public reported escapes (PREs) per km of MP main is of a similar order to that of the LP system and, hence, it is inferred that the mains must be leaking at a similar rate.
This assumption does not distinguish number of leaks and leak quantity, the physics of leakage (see section 3.2 and Spanish study in section 4.2) indicate that there should be a significant pressure effect. Indeed, our sensitivity analyses below find that ASP is the most important factor in LP mains leakage".

Response 15

The NLT programme did not test MP mains and therefore an accurate estimate for MP mains is not available. However, DNV GL agree that the physics of leakage would indicate that pressure and leakage are

proportional to one another. Therefore DNV GL accepts that the rate of leakage from a given leak will be higher due to the higher pressures involved.

It should be noted, however, the higher pressures will also skew the distribution of detected leaks. The LP network would be expected to have a larger number of smaller leaks which remain undetected for longer periods. Leaks on the MP system are more likely to be detected and rectified sooner.

Review of Joint Gas Distribution Network (GDN) response to the Energy UK Gas Retail Group Study into the effect of shrinkage on domestic customers

DNV GL has reviewed the above report and has addressed specific comments made by the GDNs.

Conclusion 16
Having reviewed the evidence presented in the report the GDNs conclude that :-

- The alternative rates from other countries used for comparisons cannot be compared to the UK without some normalisation of key drivers e.g. pressure ranges or operational regimes
- The leakage assessment methodologies presented are not as accurate as the methodology used in the UK

Response 16
The leakage assessment methodologies presented from elsewhere in the world rely on smaller sample sizes and in some cases, rely on measuring emissions in the air which are only likely to pick up leaks at the larger end of the spectrum. With regard to the conclusion relating to pressure ranges or operational regimes, DNV GL notes that, with MEG conditioning in particular, this has such an impact on leakage levels that it should be taken into account when comparing rates from other countries.

Conclusion 17
The report frequently makes reference to how the leakage rates contained within the Shrinkage and Leakage model 'contradict physical laws'. Unfortunately this conclusion is only valid if it is assumed that the leakage from mains is uniform around the circumference of the pipe barrel. Indeed it is suggested that "for all sizes of ductile iron main, the dominant failure mode is likely to be through wall corrosion". In practice through wall corrosion is rarely discovered to be the cause of gas leaks, with by far the most common cause being leakage at the joints between pipe sections. When such joint failures occur it is likely that that the leak is the result of a number of small, discrete leak paths, as opposed to the whole joint failing. Therefore, it cannot automatically be concluded that the leakage will be proportional to the pipe diameter.

Response 17
DNV GL has already addressed this earlier in the report, in response 14 and concurs with the GDNs' view that leakage rates do not contradict physical laws.

Conclusion 18
The report on a number of occasions makes reference to PE services having zero leakage rates in the shrinkage and leakage model, which is not correct.

Response 18
Once again, DNV GL has already addressed this earlier in response 2.

Conclusion 19
The report makes some reference to permeation of methane through PE mains and services, in turn creating estimates of loss rates through permeation greater than the leakage rates currently included within the SLM.

Having reviewed the documentation and sources provided in the report, the GDNs feel that the assessment of the potential permeation losses are fundamentally flawed. The vast majority of PE within the UK distribution systems is contained within the Low Pressure networks with pressures ranging from 21-75 mbarg with an average of around 30 mbarg and generally operating around 5°C. All the sources of permeation rates of methane in polyethylene quoted in the report were from tests conducted at pressures well in excess of this, usually between 1 barg and 130 barg and usually at elevated temperatures i.e. pressures 30 – 1700 times greater and temperatures significantly higher than in service mains and services would be expected to see. Whilst the GDNs do not discount the possibility that there are permeation losses from these mains, it is their belief that the permeation

rates included within the report, which are a straight extrapolation of the data points described above, are significantly in excess of what would actually be expected in practice.

Response 19
DNV GL is unable to give an expert opinion on the likely level of permeation of methane through PE mains and services. However, given that it appears to be a long term loss of gas, it is unlikely that it would be detected during leakage tests of the kind carried out for the NLT, namely pressure decay tests, and are therefore outside the remit of the review of the NLT methodology.
DNV GL accept that the permeation of methane through PE is a recognised phenomenon, and also note that results from various studies that have quantified the permeability coefficient are broadly in line with each other. Given that there is discussion about methane permeation within both the IC Consultants report and the GDNs' report, and PE forms a large proportion of the mains and services population, it would be prudent to attempt to quantify this level of gas loss, by suitable means, for inclusion in the Shrinkage estimate.
The estimates of likely methane emission from this source in the IC document are flawed, however, in that they assume operating pressure increases with pipe diameter, and this is not the case in practice. These values should therefore be recalculated with this assumption omitted.

Conclusion 20
Section 4 of the report provides an overview of leakage rates and leakage rate estimation methodologies from other countries around the world and attempts to compare them to the equivalent UK leakage rates.

Upon investigation of the sources of these comparisons specifically, that of the US and Netherlands, it is quite clear that neither of these studies come close to the volume and detail of the tests undertaken in the 2002/03 National Leakage Tests and are significantly different in their approach.

Response 20

This point is similar to that raised in conclusion 16 and has been addressed in response 16.

Discussion regarding measurement error around leakage estimate and overall conclusions

The IC Consultants report made a statement in their executive summary related to measurement error, namely :-
"It could easily be argued that the shrinkage estimate error is at least 20%, which is of the order of £15m".

DNV GL cannot find any specific evidence within the IC Consultants report to support this statement. A comparison of the errors between different leakage test programmes has shown that the UK estimate has a confidence interval of +/-19.4%, the US one is +/-65% and the Spanish tests quote +/-47%. On the basis that the UK tests consisted of the largest test programme, it is reasonable to assume that the actual error in the Shrinkage estimate could be as high as 19.4%, but the laws of statistics state that these extremes are the least likely and that a lower value would be more likely. Conversely, there is no evidence to suggest that the error is close to zero. In particularly, the lack of MP leakage tests, the aging of technology and the potential for PE permeation suggest that an error of zero is also unlikely.

It is DNV GL's view however that the test results used within the SLM should be enhanced by the addition of further tests in specific areas. This is likely to have the dual benefit of generating a more accurate estimate of overall leakage, and the larger sample size should reduce the estimate of measurement error.

The two specific areas which DNV GL advises should be included are PE mains and medium pressure mains. These additional tests should address 2 specific areas of concern, namely the level of leakage from the largest material, namely PE, and the ability to replace the current estimate for MP (using LP rates) with a rate specific to MP. Consideration should be given to novel techniques for leakage measurement where possible to reduce customer disruption.

In addition, DNV GL recommends that the population of mains and services within CSEPs should be included in the overall shrinkage estimate.

Rosemary McAll

Rosemary has 32 years experience in the gas industry. She developed the sampling plan for the 1992 NLT programme and carried out all the analysis of the test results, including the overall level of leakage and measurement error. In addition, she was responsible for providing the gas networks with alternative test sites where testing was not possible, to ensure a robust and unbiased test programme.
She also developed the Mains Risk Prioritisation Scheme for distribution gas mains which is currently being used to direct the 30 year UK mains replacement programme, the largest mains replacement programme anywhere in the world. In 2010, she received the Gas Industry Safety Group award for "Contribution to Safety in the Gas Industry in the last decade". In addition she has been a member of the International Gas Union group on gas distribution and is a fellow of the Royal Statistical Society.