Location specific assessment of risk posed by buried onshore pipelines.

It is often stated that the most likely cause of a catastrophic failure (full bore rupture) of a high pressure pipeline is external or mechanical damage. Whilst such a statement cannot be rigorously supported by historical evidence (full bore ruptures are extremely rare) it can be supported by calculation using structural reliability methods. However, the validity of the results of such calculations is heavily dependent on the validity of mathematical models and assumptions.

The computed failure frequencies associated with mechanical damage are based on the frequency at which damage is likely to occur and the computed probability that failure will occur given that the pipeline has been damaged. Procedures for determining the latter have been, and still are, the subject of some debate and this owed largely to the fact that the failure mechanism is extremely complex. However, estimates of the frequency of occurrence of damage are often accepted without question. This is because there have been a considerable number (>1000) of occurrences of damage that has allowed seemingly justifiable estimates of event frequencies to be made.

Event frequencies have been estimated by dividing the number of occurrences of damage by the operational exposure of the ‘system’, i.e. the number of kilometre years of operation. Refinements have included classifying locations as either rural or suburban, giving two different frequencies, and taking account of the fact that not all damage will have been detected. However, at present either of just two figures is used depending on whether the location is classified as rural or suburban.

Issues

One argument for continuing with this approach would be that all pipelines in rural or suburban locations are treated the same and that any differences in failure rate should be attributed to the characteristics of the pipeline rather than its location. There will clearly exist many situations where this statement is true, i.e. there appears to be nothing special about the location and hence an average incident frequency is all that can be sensibly justified. However, there will be some situations where it will clearly not be true. There may be local features present that would make excavation virtually impossible due to there being no conceivable requirement to excavate and/or present extreme difficulty in gaining access, if excavation were required. Obviously, using the average value would be conservative in these situations and hence the analysis would err on the side of caution. On the other hand there may be situations where excavations are more likely for various reasons such as close proximity of buried assets having different owners/operators.

Another issue that is very worthy of note is that the majority of the damage that has been suffered has been caused by owners of the pipeline under consideration or contractors acting on their behalf. This raises two points. Firstly, since the pipeline was being targeted (or indeed perhaps an ‘adjacent’ one) it is likely that some care (although not enough) was being exercised as the assumed depth of the pipeline was being approached. This means that the damage would be less severe than had the excavation been purely random. It also means that the frequency of occurrence of purely random events (that possibly cause the most severe damage) is likely to be lower than the average value.

The net outcome of the above is that the risks in locations where excavating activity is most likely to be undertaken by owners/operators of the pipeline are likely to be lower than would currently be estimated because the damage suffered is likely to be less severe and it would be expected that improved guidance on the excavating process would be likely to reduce the likelihood of impact further.

On the other hand, although the rate of occurrence of random events is much lower than what is being currently predicted, the severity of the damage is likely to be worse than what is being predicted, i.e. the deepest gouges and dents are likely to be caused by the random event.

Further interrogation of available data would be worthwhile to allow more focussed site specific risk assessments to be undertaken in situations where the use of average incident rates are open to challenge.

At present in a given location a single incident frequency, f , is used and the failure frequency is given by

$$f_f = fp(f \mid I) \qquad (1)$$

where $p(f \mid I)$ is the probability of failure given an incident.

Suppose that the incidents are categorised as incidents caused by operators (or their contractors) , I_O , and incidents caused by third parties, I_{TP} , and that these occur with frequencies, f_O and f_{TP} , respectively, where $f = f_O + f_{TP}$.

If we temporarily assume that both types of incident are random, i.e. are not affected by location, then the failure frequency is given by

$$f_f = f_O p(f \mid I_O) + f_{TP} p(f \mid I_{TP}) \qquad (2)$$

where $p(f \mid I_O)$ and $p(f \mid I_{TP})$ are the probabilities of failure given events caused by operator and events caused by third parties respectively.

Noting that the relationship

$$p(f \mid I) = \frac{f_O}{f}\, p(f \mid I_O) + \frac{f_{TP}}{f}\, p(f \mid I_{TP}) \qquad (3)$$

must hold, it is easy to see that the failure frequencies given by (1) and (2) are identical. This means that if incidents caused by operators and third parties are treated as randomly occurring events then the failure frequency that would be deduced from the ‘averaged’ expression (1) would be identical to that which would be deduced from the more resolute expression (2). However, we see that if local conditions dictate that third party access were not possible, or extremely difficult, then the failure frequency would be given by

$$f_f = f_O \; p(f \mid I_O)\,. \qquad (4)$$

This would be lower than the average value by virtue of the reduced incident frequency and also the reduced failure probability (assuming that the damage caused by operators is less severe than that caused by third parties).

Also suppose that improved procedures are resulting in fewer incidents caused by operators then the failure frequency would be given by

$$f_f = f_{TP}\, p(f \mid I_{TP}) \qquad (5)$$

This would result in a reduced value but it should be noted that $p(f \mid I_{TP})$ could be considerably higher than $p(f \mid I)$ due to more severe damage being caused by third parties.

The above analysis reveals that in some situations the risks may be considerably lower than those that would be inferred from the current risk assessment methodology. This, of course means that the current approach is conservative and is hence safe (Assuming that underlying structural mechanics is not un-conservative). However, it also means that unreserved use of the averaged approach could lead to unnecessary prevention of development in some situations.

Nonetheless, whilst the above, is based on reasonable conjecture it requires some validation before it can be used with a good level of confidence. Further analysis is thus required and, towards this end, it is recommended that ratio of the incident frequency ratios f_O / f (and hence f_{TH} / f) is determined (in rural and suburban locations) and that the damage distributions pertaining to events I_O and I_{TH} are determined.

Data requirements

Third party incident database including record of whether third party or operator / contractor