Steel Corrosion Model Interpretation

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1 INTRODUCTION

Models have been developed representing several failure mechanisms of steel pipework in the UK gas network.

These models predict failure likelihood based on several factors. This report presents an engineering interpretation of these factors.

2 INTERPRETATION OF MODELS

2.1 Detection and reporting of leaks

Much failure data is reported by members of the public reporting leaks. The population of steel assets is likely to contain a significant proportion of unrevealed faults, which represent failures that are undetected and not contained in the data. Different types of faults are expected to be more or less likely to be detected. Small pinhole corrosion may perforate a pipe wall but because of its location and the volume of gas released not be detected. Relatively remote pipework may be expected to carry more unrevealed faults than equipment in more densely populated areas.

So the strength of relationships between factors found in the models must to some extent reflect this aspect of data capture.

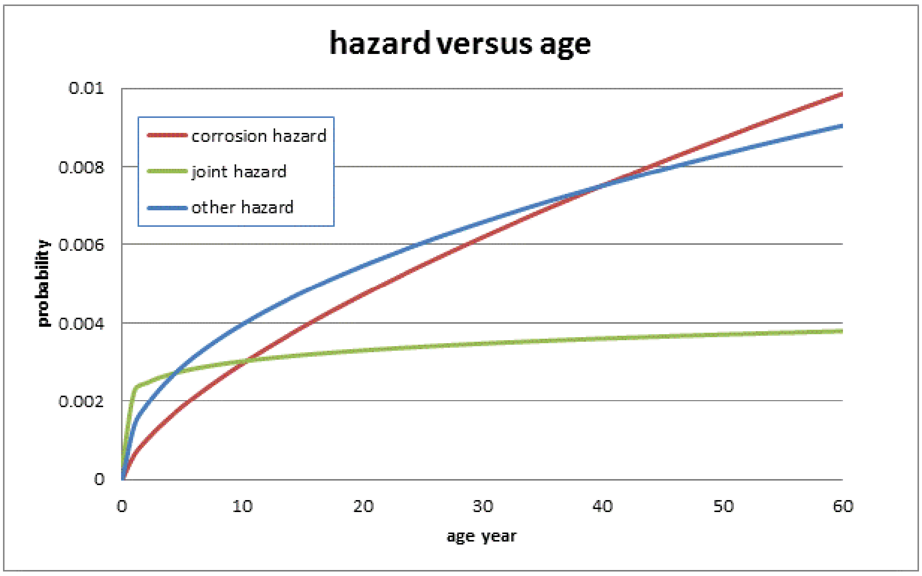
2.2 Asset age and records

For a model of a deteriorating asset, its age is an important property. The records of age of the oldest assets were poor and had serious inconsistencies. Failure records were not available from end of the last century. The consequence of this was that the oldest assets were omitted from the modelling process, and there is a period where early failure events were not recorded.

3 HAZARD

The hazard function represents the probability of failure, conditional on having survived up to that point. The hazard function is also known as the ‘instantaneous failure rate’.

If the hazard function rises with time, it indicates that vulnerability is increasing with age due to wearout. If the hazard function decreases with time it indicates that specimens in service have less vulnerability, because weaker specimens have failed early.



Default fits to

Corrosion;	Shape =1.673,	Scale =111.669	(Intercept = 4.71)
Joint;	Shape =1.126,	Scale =248.2	(Intercept=5.514)
Other;	Shape =1.46,	Scale =118.14	(Intercept=4.772)

3.1 Shape term

The corrosion and other models both have shape factors around 1.5, indicating vulnerability is increasing with age. In the statistics of corrosion science the relationship between pit depth and time is commonly reported as a mean pit depth rising in proportion to time raised to a power. The values quoted for the power range from 0.33 to 1, with 0.5 the most common. Separately the statistical modelling of corrosion pit depths often follows an extreme value distribution where the model parameters characterising pit depth rise to a power of time. These two time dependent factors together are consistent with a Weibull distribution having a shape factor greater than one, indicating a progressive increase in likelihood of failure.

For each recorded corrosion failure event, a value of nominal corrosion rate has been derived based on the estimated wall thickness at the location. These are actual failures, so the data is not a random sample. Failures are arising that suggest corrosion rates of about 0.23 mm/year. This corresponds to the higher levels of reported metallic pitting corrosion, given in report RP6625. Pitting corrosion is probabilistic, and the more surface at risk the greater the likelihood of a failure to be observed. This suggests that the observed failures, are observations of extreme corrosion events on a large amount of at risk surface.

The joint model has a shape factor close to one, this indicates that the probability of failure is not strongly increasing with time. Failures are occurring, but at close to a constant rate. This suggests that although the equipment is not wearing out, it is prone to systemic failure. It might be argued that the incidence of joint failure raises engineering issues related to the suitability of steel joint design.

4 MODEL FACTORS

4.1 Soil term

The model Scale values represents the elapsed time for 63% failure of population. Therefore a reduced scale value shortens the time to failure. The adjusted Scale value for soil1 corresponds to 219 years, soil2 to 195 years and soil3 to 183 years.

This suggests that the failure data is consistent with more corrosive soil giving rise to conditions of higher corrosion rates. There are soil factors effect found for joint and other models, but at a reduced level compared to the corrosion model, consistent with a lesser importance of soil as a predictor.

4.2 Zone term

The recorded failure rate of assets near to the asset in question has been used to create a zone factor that rises from 1 to 3. Factor are based on the total number of failures, for each specific model type being divided by the mains length within 400m. A value of one corresponds to no nearby assets having yet failed. All three models show a consistent zone effect, with proximity to assets with a high failure rate indicating earlier failure likelihood.

For corrosion failure, it is possible that the local soil conditions are corrosive and this is causing nearby failures giving rise to the zone factor. In this regard the zone factor would be a stronger marker of local area soil chemistry than the soil term taken from the database.

For joint models, the zone factor probably indicates nearby joints are similar to the joint in question, and subject to similar conditions. For the other models, there may be an element of corrosion at work in giving rise to failure and if so, the local soil conditions would be expected to influence failure.

4.3 Urban versus rural term

The factor ‘Urban’ reflecting whether an asset is in an urban or rural area shows only weak influence for Joint and Other models, and is not predictive at all for the corrosion model. Higher urban compared to rural traffic loading might be expected to generate more joint leaks, and higher numbers of people in urban areas in the vicinity of pipes may also contribute to leak detection and reporting.

4.4 Diameter term

Diameter affects corrosion failure, with medium diameter more at risk than small or large. The expected deepest pit from pitting corrosion rises with increasing surface exposed, but the time to perforate will rise with increased thickness. It might be expected that a medium diameter of pipe offer the combination of most surface and thinnest wall thickness and therefore the finding that it is most at risk of failure is consistent.

For the joint model, small diameter was a least risk, and both medium and large diameter at much reduced likelihood of failure. It is expected that the type of joint on small diameter pipes would be predominantly screwed, whereas medium and large diameter will be flanged or sockets and held by some form of bolts. Many joint leaks are repaired, consistent with the dominant failure type being a result of flange joint opening or bolt failure.

The other failure model shows a similar effect with failure least likely on small diameter mains, with similar likelihood for both Medium and Large. It may be that fittings that give rise to ‘Other’ failure are characteristically different on small diameter pipes compared to large and medium pipes.

4.5 Pressure term

Internal gas pressure might not be expected to be an influencing factor on causing pipe corrosion. Medium pressure is predicted to be slightly less at risk of causing failure than low pressure.

There is expected to be little difference in wall thickness between low and medium pressure pipes, and the higher leakage rate from a defect in a medium pressure pipe might be expected to increase the likelihood of detection. The construction and coating standards applied to medium and low pressure pipes historically have been similar.

Medium pressure pipework is predicted to be slightly less at risk of causing failure than low pressure in regard of joint failure. There is expected to be little difference construction and design standards between low and medium pressure pipes, and the higher leakage rate from a defect in a medium pressure pipe might be expected to increase the likelihood of detection.

The Other failure model find no difference is failure probability between low and medium pressure. Intermediate pressure is found to be at much less risk of failure, perhaps because of different construction practices, increased welding and fewer joints and fittings.

Overall, the same size of defect on a medium pressure pipe will release more gas than a low pressure pipe, by virtue of increased gas density and increased differential pressure.

But it is considered most probably that medium pressure mains tend to be more remote from people, and perhaps also less trafficked and subject to less interference risk.

It may be that Medium and Low Pressure pipes are failing at a similar rate but that the increased likelihood of detection from the volume of a medium pressure escape is compensated by the more remote location of the medium pressure mains.

4.6 Length term

All models predict that longer mains are more likely to fail, and that risk rises in a consistent way with length. Six factors are used for length from rising from up to 5m to over 80m. The value of the factors for corrosion and other models are similar in magnitude. But the length effect factors are consistently larger for the joint model terms.

When length increases and corrosion surface increases the probability of a deep pit developing, in accordance with extreme value pitting theory is not linear, but varies approximately with the log of the area. However when considering the joint model, additional length will contribute additional at risk joints in an approximately linear manner.

5 THE IDENTIFICATION OF CANDIDATE REPLACEMENT SCHEMES

When mains are to be identified for replacement it is desirable that groups of high risk assets are located in proximity to one another and preferably connected one to another.

Rather than separate pipe assets, all those sections of connected mains could be identified. This could produce a separate list of groups of connected mains.

For this list of groups of connected mains the combined hazard could be derived, corresponding to each failure model and overall.

- For each group of mains an overall and per meter of length hazard score could be derived.
- A geographic centre of each group could be derived.
- Groups themselves could be assessed for proximity to other groups by means of a grid.
- A grid could be applied and an overall hazard score derived based on the groups within the grid.
- Thresholds could be able to be set, such that only groups of connected mains over a specific length and above a specific hazard are counted.
- Locations of potentially feasible groups of candidate assets for replacement could be identified for further assessment and review