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Lifetime of polyethylene pipelines under pressure

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Lifetime of polyethylene pipelines under pressure

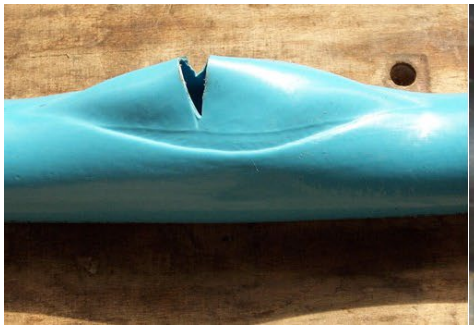
The reliable working lifetime of plastic pipes for water supply systems can be shown to be in excess of 200 years[1]. For natural gas or hydrogen supply systems, it will be longer. This is a critical piece of information when managing long-term investments in assets and it is important that the evidence to support this claim is sound.

The reliable working lifetime should not be confused with the 'design life' which is a 50-year design point used by manufacturers to classify different polyethylene materials. Through testing and analysis of results it is possible to predict the strength at 50 years of a pipe working at 20°C.

Predicting failure

Polyethylene pipes in service do not suffer from corrosion-related defects which can be hard to predict due to the nature of fluid transported, soil conditions, and proximity of other services.

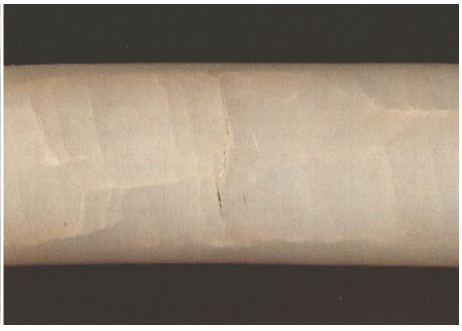
The failure modes of a polyethylene pipe are predictable. They have three time-dependent failures modes, variously referred to as ductile rupture, stress crack rupture or oxidation breakdown.



Ductile rupture, independent of time, a very high internal pressure can exceed the strength of the pipe causing it to stretch and fail in a ductile way.



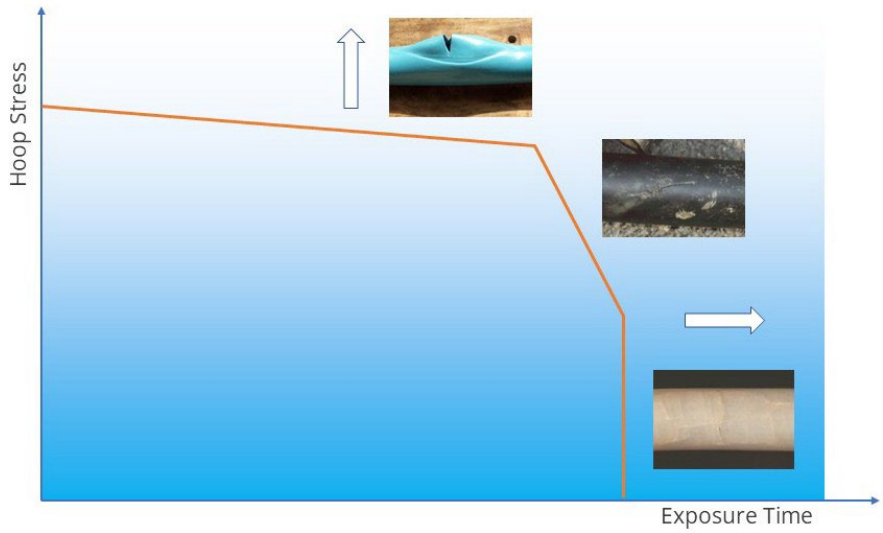
Stress crack, at lower pressures but much longer timescales, the reliable lifetime limit could be brittle crack grown through the material.



Oxidation, largely independent of pressure, at very long timescales, the likely reliable lifetime limit will be as a result of polymer oxidation.

Predicting performance

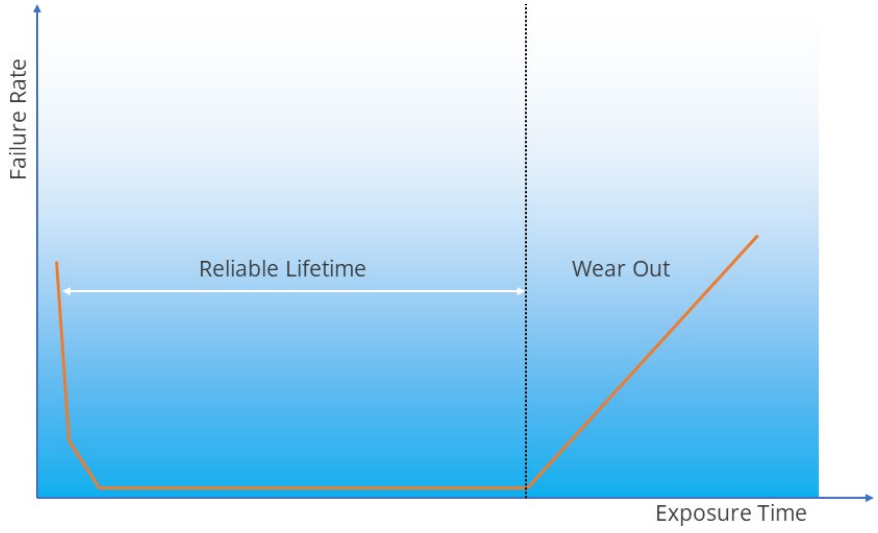
Each of these failure modes occurs at a point in time which can be predicted, is a function of the stress applied to the material by the internal pressure in the pipeline and the operating temperature.



An envelope of performance can be constructed, using Arrhenius[2] equations, describing when these failure modes can occur in time.

From the predictable failure modes, it is possible to see where the transition from the 'reliable working lifetime' moves into the 'wear out' mode. Pipelines continue to operate in the 'wear out' phase but a different operational management might be introduced.

This bathtub reliability engineering model is one way to show the lifetime of a polyethylene (or other plastic) piping system. Knowledge of the onset of stress crack and oxidation failure modes will inform pipeline owners of the time to the 'wear out' phase'.



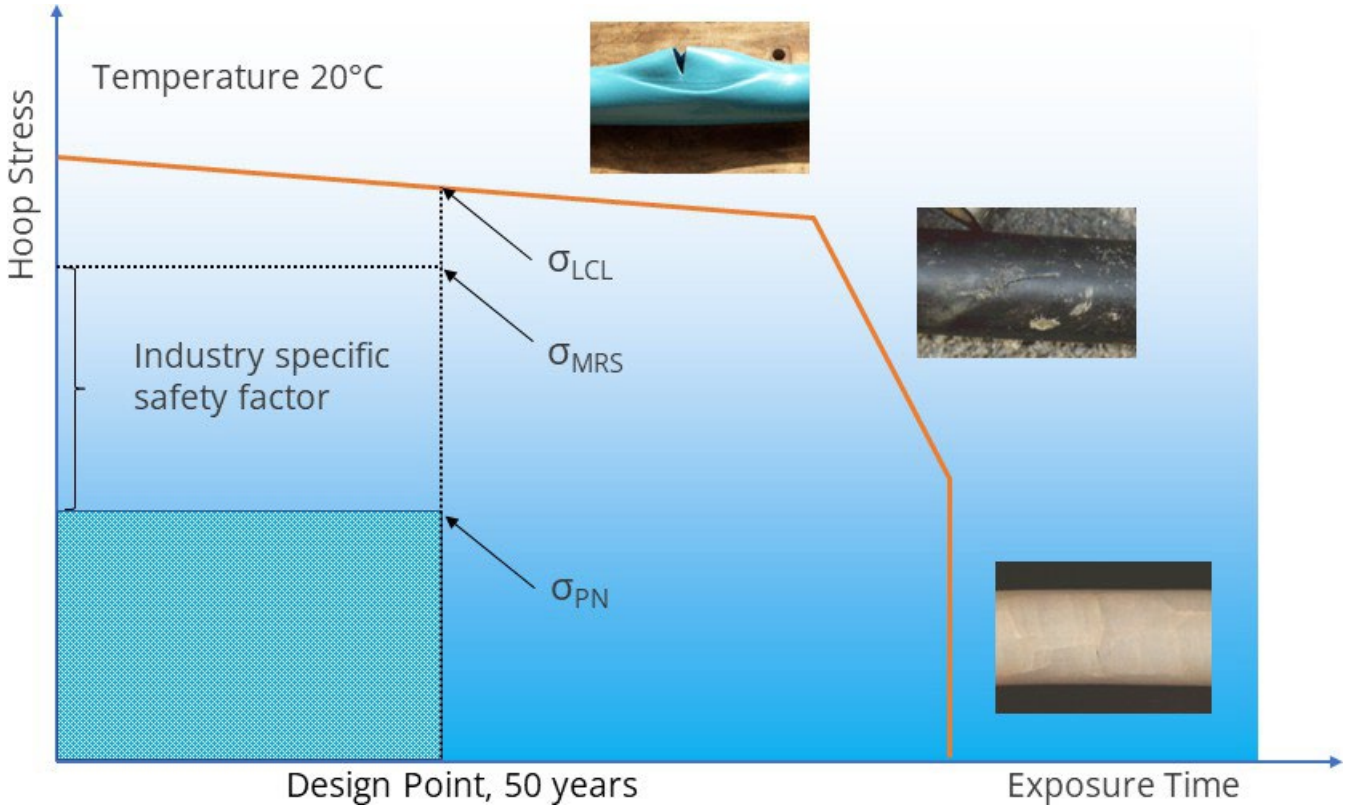
UK experience shows that drinking water pipes will exhibit the late life failure modes sooner than gas pipes, as chlorine initiates an oxidation degradation mechanism. Research by water companies and manufacturers show that for the earlier generation materials transition to 'wear out' will likely start at around 235 years[1].

Designing a reliable product

To ensure that every polyethylene pipe performs well, pipes are classified according to their predicted strength at a given time and operating conditions.

Design point (design life): In the UK, in common with much of the world, the given time (the design point) is 50 years. The strength is predicted from test data at an operating temperature of 20°C.

Factors of safety: The predicted strength is rounded down to one of the agreed classifications, so a value of 10.8 MPa is rounded to 10 MPa (PE100 pipe). An industry safety factor is applied, in the UK for gas this is a minimum of 2.9 and for water 1.25.



So, by applying the 50-year classification system, pipe is operating a long way from the predicted failure points.

Real lifetimes can be achieved that are measured in hundreds of years. As industry continues to invest in new materials, these will continue to extend as resistance to stress crack, and oxidation effects improve.

Supporting evidence

A technical paper '*100 years lifetime of Polyethylene pressure pipe systems buried in the ground for water and natural gas supply*' is available from TEPPFA, the trade association for the plastic pipe and fitting industry in Europe, which details the international standards and testing undertaken by manufacturers on new products and exhumation trials on pipelines which have been in service for many years (www.teppfa.eu/media/position-papers/a-position-100-years-lifetime-of-polyethylene-pipe/).

References

1. Hoang E.M., Lowe D., "Lifetime prediction of a blue PE100 water pipe", Polymer Degradation & Stability, Issue 8 (2008), pp 1496-1503

2. Svante Arrhenius, 1859-1927, in physical chemistry, development of equations for the temperature dependence of reaction rates, a fundamental of accelerated ageing techniques in the field of reliability engineering.