WHITE PAPER

IMPORTANCE OF MATERIAL PROPERTIES DATA IN POLYETHYLENE PIPE DESIGN

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Qenos

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Find out about how material data supplied by PE resin manufacturers leads to more cost-efficient pipelines
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BY APPLYING THE ACTUAL PERFORMANCE DATA OF THE SELECTED PE100 RESIN WHEN DERATING OR APPLYING OF RISK FACTORS, PIPELINE ENGINEERS CAN BENEFIT FROM THE IMPROVED PERFORMANCE OF ADVANCED PE100 RESINS AND DESIGN MORE COST-EFFICIENT AND HIGHER PERFORMING PIPELINES – POTENTIALLY SAVING THOUSANDS OF DOLLARS.

Increasingly, engineers are specifying polyethylene pipe in new or replacement networks for the transport of water or gas.

Once the material and installation technique have been selected, engineers apply industry standard formulas to design the diameter and wall thickness of the PE pipe that will be suitable for the flow and pressure required for the network.

Risk factors are then applied to account for any potential risks that may be encountered by the pipe during installation or in use.

Often, pipe engineers use generic, base-line data to apply risk factors that "de-rate" the pipe – adding to the wall thickness and material costs.

WHAT ARE THE CHALLENGES THAT ENGINEERS FACE WHEN DESIGNING PIPELINES?

To ensure minimum design, construction and safety standards are met, it is common practice for engineers to follow prescribed guidelines set out in industry standards. The standards and procedures cover product and installation specifications relevant to the requirements of the application. However, following this prescribed design route may result in the addition of unnecessary costs or less than optimal operating conditions since:

- Not all PE100 grade pipes are the same. It is important to know the specific performance criteria of the PE100 resin used to produce the piping in order to optimize design.
- Opportunities to design for purpose – taking account of pressure, flow, temperature, installation and location conditions and based on actual material data – are missed.
- Purchasing PE100 grade pipe without establishing a relationship with the supplier could impede flow of valuable information.

Pipe diameter and wall thickness are key characteristics of pipeline design that impact on all project-related costs from materials and manufacturing, to transport and installation. Understanding the actual properties of the PE material mitigates against over-specifying the pipeline at the design stage – especially the wall thickness specification or operating conditions– while ensuring optimum, safe performance.

WHAT PROPERTIES ARE IMPORTANT TO CONSIDER?

The latest grade of high-density polyethylene PE100 resins offer engineers the opportunity to design pipe networks using the 'fit for purpose' method rather than follow a prescribed route. This approach is used extensively in the coal seam gas (CSG) industry and is equally beneficial for water and gas supply, mining, irrigation and waste management industries.

> USING ACTUAL PE MATERIAL DATA ALLOWS ENGINEERS TO DESIGN MORE COST-EFFICIENT PIPELINES – POTENTIALLY SAVING THOUSANDS OF DOLLARS

Since they were first introduced in the 1960s, the physical properties of PE pipe materials have continued to evolve. In addition to improvements in the Minimum Required Strength (MRS) rating, developments in the polymerisation process of some resins have led to an increase in resistance to both slow crack growth and rapid crack propagation and these materials now provide improved performance at elevated temperatures – all important properties that affect the final performance of the pipe beyond the generic class of PE100 resins.

WHAT IS THE DIFFERENCE BETWEEN PRESCRIBED DESIGN AND FIT FOR PURPOSE DESIGN?

In Australia, industries such as water distribution or coal seam gas extraction issue national codes and regulations which include product and installation specifications relevant to the requirements of the particular segment. The industry agency can make decisions independently of the prescribed design approach provided it is supported by the most up-to-date technical knowledge and operational practice. For example, the code of practice used in the coal seam gas industry allows “Prescribed Design” and “Fit for Purpose Design” to be used individually or together to complete a pipeline design [1].

Prescribed Design uses a series of formulae and tables derived from theoretical considerations and industry standard practice. Typically, industry standards specify the physical properties of pipes used to transport fluids under pressure. Specifications are provided regarding dimensional requirements and maximum operating pressure related to the service (design) factor and operating temperature.

To calculate the pipe design stress, S, and pipe dimensions, such as pipe wall thickness for a designated pipe diameter, the Minimum Required Strength (MRS) of the pipe material is divided by the overall Design Factor, F.

The pipe wall thickness requirements can be calculated from the following equation:

$$T_{min} = \frac{PD_{m\,min.}}{2S+P}$$

where

P = maximum design operating pressure of pipe, in MPa

$D_{m\,min.}$ = minimum mean outside diameter, in mm

$T_{min.}$ = minimum wall thickness of pipe, in mm

S = MRS/F, hydrostatic design stress at 20°C, in MPa

F has traditionally been used to account for unpredictable variations in material assessment and the design parameters for a specific installation and operating conditions. Given there is variation in all processes including production of pipe material and subsequent testing to determine MRS, a judgment based value of greater than 1.0 is used as the factor of safety. For PE pipes, the design factor is never less than 1.25.

The application conditions-related component of the overall design factor is left to the application engineer to incorporate via individual design safety factors (*f*x). These relate to the location of the pipeline, the operating pressure, type of fluid being conveyed, installation method, hydrostatic and dynamic loading, in addition to other considerations specific to the application. Recommendations on the selection of appropriate factors for the design of pipes are given in relevant Standards. A typical example of the application conditions related component of the design factor, F, is:

F = f_0 (Fluid)x f_1 (Temperature)x f_2 (Installation depth x f_3 (Installation method)

Fit for Purpose Design relies on a study of a real and present situation and the use of a rigorous risk assessment process to derive one or more of the factors used in the prescribed design case.

Fit for Purpose Design offers the opportunity for pipeline designers to utilise actual material data and advances in PE100 resin properties to design more efficient pipelines, especially in the calculation of the “*f*” risk factors used in calculating the overall design factor, F. This approach is used in gas [1] and water [2] industry applications [3,4].

WHAT IS TEMPERATURE DERATING AND HOW COULD AN ENGINEER BENEFIT FROM USING ACTUAL DATA?

Temperature derating refers to the value used for the operating temperature factor, f_1, in the design factor, F, equation.

The standard, minimum requirement is based on material testing up to 80°C over 1 year. Obtaining extra test pressure data on the PE100 resin for use at higher temperatures is an example of how Fit for Purpose Design could be utilized.

Data from the resin manufacturer’s pressure tests, measured at high temperatures (up to 80°C) over 2 years, allows a designer to apply the performance of the specific PE100 resin being used in pipe manufacture. This gives designers the capability to optimise pipeline design for the desired temperature and lifetime and may allow a reduction in pipe wall thickness and material usage – or allow the pipe to be operated under higher flow, temperature and pressure conditions.

Pressure data collection at elevated temperatures in the Qenos Technical Centre, Altona

WHAT CAN BE DONE TO ASSESS THE APPLICATION OF OTHER RISK FACTORS?

As each individual risk factor (f) making up overall design factor, F, potentially results in an increase in the wall thickness, Fit for Purpose Design can also be applied to determine the fluid design factor (f_0), installation method (f_2) and location (f_3) risk factors.

For example, the location factor takes account of the risk of mechanical damage to the pipeline by first or third parties according to whether it is to be laid in a high density urban area, semi-urban or rural location. The location may require a design which offers greater contingency in terms of depth of installation, adjusted design factors or assessment of the contingency built into the PE100 resin performance. The last of these considerations includes assessing the PE100 resin's resistance to slow crack growth - data that is available from the resin manufacturer.

WHY CAN'T A PIPE BE DE-RATED USING MRS RATING ALONE?

Pipe design cannot be undertaken with consideration of a single property in isolation. For each application, the product standard guidelines require that additional mechanical and physical property performance benchmarks are met.

All PE100 grade resins have a Minimum Required Strength (MRS) specification of ≥10.0 MPa, which is an improvement on previous generation resins. While MRS is an important indicator of the pipe's ability to withstand pressure, it doesn't indicate a pipe's resistance to brittle failure. This is addressed only by selecting PE piping made from PE100 resins with high stress crack resistance (HSCR), such as Qenos Alkadyne HCR193B resins.

WHAT DOES AN ENGINEER NEED TO CONSIDER WHEN ASSESSING TRENCHLESS INSTALLATIONS?

The flexibility of PE piping enables installation techniques to be used that are cheaper, quicker and less disruptive than open trench methods. These "trenchless" methods are more demanding on the pipes, as long-lengths of PE piping are dragged through pre-drilled holes below ground or through existing pipe. To withstand damage to the wall of the pipe from abrasions during installation that increase the risk of brittle failure, the design engineer can either select a more resilient material or increase the f_2 risk factor that would lead to thicker pipe walls. The latest class of PE100 HSCR resins is suited to these harsh handling conditions due to their inherent resistance to slow crack growth and ability to be pulled, bent and welded.

SOURCING MATERIAL DATA: HOW THE RESIN SUPPLIER CAN HELP

Qenos has extensive experience in testing and analysing PE pipes and its technical services team can provide valuable material data to engineers on request to support design decisions relating to risk factors. Typical data sets include:

- Minimum Required Strength (MRS) data.
- Temperature/pressure data over extended time periods and at elevated temperatures.
- Resistance to slow crack growth testing data obtained under varied conditions.

CONCLUSION

By selecting a PE resin based on its actual physical properties and using Fit for Purpose Design, engineers can optimise the risk factors to design a cost-efficient network with:

- Higher performance benchmarks for pipelines by optimizing flow, temperature and pressure.
- Thinner walls – requiring less PE resin – while meeting all performance and safety criteria.
- Physical characteristics that make it suitable for faster, less-disruptive and cheaper trenchless installation methods.

REFERENCES

1. Australian Pipeline and Gas Association (APGA) Code of Practice for Upstream Polyethylene Gathering Networks in the Coal Seam Gas Industry, Version 4, October 2016, apga@apga.org.au
2. Water Services Association of Australia, WSA 01-2004 Polyethylene Pipeline Code Version 3.1
3. AS/NZS 4130:2009 Polyethylene (PE) pipes for pressure applications
4. AS/NZS 4645.1:2008 Gas distribution networks

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