WHITE PAPER

PE100 HSCR FOR TRENCHLESS PIPELINE INSTALLATIONS

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Find out how PE100 HSCR provides pipelines with a higher safety margin against slow crack growth failure and enables “fit for purpose” design.
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Trenchless installation of polyethylene pipes is steadily gaining market acceptance as a method that provides both improved cost efficiency and reduced disturbance to the community and environs. However the increased exposure of the pipe surface to damage that is inherent in many of the trenchless techniques may lead to an increase in the potential for premature failure from slow crack growth linked to damage to the surface of the pipe. Engineers commonly specify thicker walled pipes in trenchless installations to lower the risk that any surface defects exceed 10% of the pipe wall thickness. PE100 HSCR, a new class of PE100 resin with High Stress Crack Resistance, enables the use of less conservative pipeline design safety factors in trenchless installations, thereby reducing material usage, improving flow characteristics and shortening welding time.

THE DEPTH OF NOTCHES IN POLYETHYLENE PIPELINES ARE LIMITED TO 10% OF THE WALL THICKNESS TO ENSURE AN ADEQUATE SAFETY MARGIN AGAINST FAILURE FROM SLOW CRACK GROWTH. PE100 HSCR PROVIDES HIGHER PROTECTION AGAINST THIS TYPE OF FAILURE EVEN AT NOTCH DEPTHS OF 30% OF THE WALL THICKNESS.

Polyethylene (PE) has a track record spanning over 50 years in pipeline applications and exhibits one of the lowest failure rates amongst pipe materials. Nonetheless, failures do occur and research indicates that the greatest threat to the structural integrity of a pipeline comes from external interference. Such damage can occur during installation or afterwards when for example excavation works are being carried out in the vicinity of the pipeline. PE pipes need to sustain their pressure loading for many years and show long-term resistance to creep rupture through “ductile” failure. However, as fairly conservative safety factors are used in pipe design, PE pipes have a large safety margin for pressure bearing capability and do not fail in over pressured “ductile” mode in real life operations.

The most common mode of failure for pressure pipes in service is “brittle” failure through the slow crack growth (SCG) failure mechanism. A slow growing crack may initiate and grow in the presence of a localised stress field, leading to failure within the expected service life of the pipeline. Crack initiation can be the result of damage to the pipe during transport, trenchless installation (scores, scratches and gouges), or later in service resulting from point loading due to rock or root impingement. Bending caused by ground movement can also impose additional stress on the pipe, thereby accelerating crack growth. Consequently, the resistance of the base PE to the initiation and subsequent growth of cracks originating from localised stress points is a key determinant in ensuring the long service life of PE pipelines.

Pipeline integrity is dependent on the design, operation and management of the pipeline. A safe pipeline starts with good design and the selection of a polyethylene pipe resin with sufficient stress crack resistance to enable it to withstand the demands of the installation and ongoing operation.

A rule of thumb has long been relied upon to minimise the likelihood of premature failure due to slow crack growth. This rule has been specified into installation standards and limits the maximum allowable depth of scratches, indentations and dents in PE pipe during installation to 10% of the wall thickness.

> THE RESISTANCE OF THE BASE PE TO THE INITIATION AND SUBSEQUENT GROWTH OF CRACKS ORIGINATING FROM LOCALISED STRESS POINTS IS A KEY DETERMINANT IN ENSURING THE LONG SERVICE LIFE OF PE PIPELINES.

WHAT ARE THE CONCERNS?

Trenchless installation techniques such as pipe bursting, slip- and swage-lining, and horizontal directional drilling, bring installation advantages both in cost efficiency and in minimising disturbance to the environment where the pipe installation is taking place. However these techniques have the potential to cause damage to the surface of the pipe, which could compromise pipe service life. For example in the pipe bursting process, the new pipe is exposed to potential damage arising from contact with the pipe being replaced, typically through contact with fragments of cast iron, clay or reinforced concrete pipe.

ASTT has published guidelines for trenchless construction (ASTT, 2009) which states in relation to pipe bursting[1]; *"Exterior pipe damage assessment is difficult to carry out and detect once installation is completed. Inspection for exterior damage should be carried out prior to installation to ensure the integrity of the pipe. Hydrostatic testing should also be performed prior to installing the pipe to ensure any defects are addressed. One of the common practice testing techniques is to pull out 2 – 7m of pipe and examine it after installation from the receiving chamber. This front section of the pipe tends to receive the most impact and damage from the installation process and is used as a guide for determining the general condition of the rest of the pipe."*

These guidelines, whilst useful and adopted in practice, only partially address the potential for damage. The assumption that the "front section of the pipe tends to receive the most impact and damage" is not always the case. Scratches in the surface of the pipe are localised areas of stress concentration that may lead to eventual failure arising from slow crack growth. While the practice of examining the leading end of the inserted pipe as it exits provides a degree of confidence, the examination does not ensure that there is no further damage. In addition, hydrostatic testing is a short term test method and cannot reveal the type of damage to PE100 pipe that is linked to the long term slow crack growth failure mode.

Concerns regarding the effects of surface damage may be addressed by the use of sacrificial pipe jackets. This approach adds cost and introduces the risk of interface de-cohesion which has been known to occur in multilayer pipes.

Pipeline designers looking for a greater level of certainty may choose to use higher safety factors which specify thicker pipe walls. In the horizontal directional drilling (HDD) of large bore pipes, SDR11 is typically sufficient to accommodate the high pulling forces and eliminate the risk of buckling. In cases where there is particular concern about pipe damage during installation the designer may choose to specify SDR9 pipes, though this will reduce throughput capacity and increase project costs.

HOW IS THE TOLERANCE TO SLOW CRACK GROWTH CAUSED BY NOTCHES MEASURED?

For PE100, AS/NZS 4131 requires a minimum of 500 hours at a stress of 920 kPa in the notched pipe test on SDR11 pipe in accordance with ISO 13479. In this test the pipe sample is notched in a standardized procedure to 20% of pipe wall thickness. The pipe is then pressurized to a stress of 920 kPa at 80°C and the time to brittle failure is recorded.

For PE100 HSCR (High Stress Crack Resistant), PIPA guideline POP016 outlines the following requirements[2]:

These additional requirements warrant that PE100 HSCR has a slow crack growth resistance that is significantly higher than that of conventional PE100.

Test	Minimum Requirement
NPT	5000 hours at a stress of 920 kPa in the notched pipe test (NPT) on SDR11 pipe in accordance with ISO 13479
FNCT	8760 hours in the full notch creep test (FNCT) according to ISO 16770
2NCT	3300 hours in the 2 notch creep test (2NCT) according to EN 12814-3
PLT	8760 hours in the point load test (PLT) according to DIN PAS 1075

HOW PE100 HSCR PROTECTS AGAINST SLOW CRACK GROWTH

Notch depth testing program

In order to assess performance with deeper notches, Qenos tested Alkadyne® HCR193B – a PE100 HSCR listed in PIPA guideline POP004[3] – in the notched pipe test with notches of depth greater than the standard 20%. The Notch Pipe Test simulates the damage that may occur during the installation of the pipe. This more aggressive test was designed to determine whether pipe made using Alkadyne® HCR193B could withstand deeper notches at test times beyond that required by the standard (AS/NZS 4131). All tests were conducted at 80°C and at 920 kPa internal pressure as required by AS/NZS 4131.

This test revealed that Alkadyne® HCR193B exceeds the slow crack growth resistance specifications for PE100 even with notches at 30% of the wall thickness as shown in Figure 1. This data supports the case for using PE100 HSCR in trenchless installations where there is a risk of deeper notches.

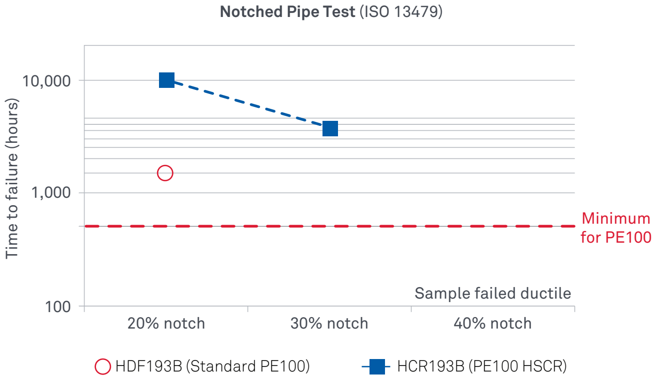

Figure 1: Notched Pipe Test according to ISO 13479 with varying notch depth. Test covered 110 mm SDR11 pipes with varied notch depth tested in hydrostatic pressure test at 920 kPa/80°C.

"Fit for purpose" pipe design

The additional safety margin for slow crack growth resistance provided by PE100 HSCR opens the door to rethink "fit for purpose" pipe design. The practice of increasing wall thickness (specifying a lower SDR) to address concerns of potential failure through the slow crack growth mechanism may be unnecessary when using PE100 HSCR.

Installation standards such as the newly released APGA code of practice for upstream PE gathering networks in the CSG industry allow for "fit for purpose" design when materials other than conventional PE100 are used[4]. Pipes made from Alkadyne® HCR193B featuring DN110 mm with varying wall thickness have been evaluated in the notched pipe test with a constant notch depth of 2.1 mm, as shown in Figure 2. The results indicate that a pipe made from HCR193B with SDR13.6 exhibits an equal or higher safety margin to slow crack growth failure compared to standard PE100 SDR11 pipe with the same notch depth.

In the prior example of large bore pipes installed by HDD, the selective use of PE100 HSCR in the sections of the pipe most vulnerable to damage could enable the use of SDR11 across the entire installation. In addition to reducing material usage, improving flow characteristics and shortening butt welding time, this would eliminate the requirement for adapters to connect the sections with different SDR and significantly reduce installation time.

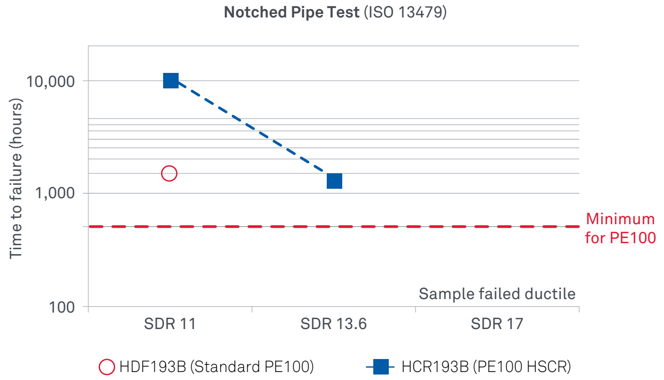

Figure 2: Notched Pipe Test ISO according to ISO13479 with varying wall thickness. Test covered 110 mm pipes of varying wall thickness with constant notch depth of 2.1 mm tested in hydrostatic pressure test at 920 kPa/80°C.

REFERENCES

1. Australasian Society for Trenchless Technology (ASTT) 09-2009. Guidelines for Horizontal Directional Drilling, Pipe Bursting, Microtunneling and Pipe Jacking, Sep 2009, www.astt.com.au
2. PIPA Industry Guideline POP016 05-2016. High Stress Crack Resistant PE100, www.pipa.com.au/
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