High Stress Crack Resistance
BorSafe PE100 for the toughest conditions
High Stress Crack Resistant Materials for Additional Security

**PE is the pipe material for the 21st Century**
Over the last forty years polyethylene pipe has seen a sharp rise in popularity amongst utility companies due to its ease of use and good track record. As the confidence in PE has grown, engineers have sought to reduce installation costs by using less imported backfill materials and more trenchless installation methods. Both of these tend to increase the surface damage and the stresses on the PE pipes demanding even greater toughness and durability from the PE material.

PE pipes are also now being used in the oil and gas industry and the mining industry to line steel pipelines to protect them against corrosion and abrasion. The lining process is usually carried out using “swagelining” or a similar “close fit” insertion technique which can also create additional surface damage and stresses in the PE pipes.

**The increasing demands on PE pipe**
The use of “selected as-dug” materials to backfill the pipe or the use of trenchless installation techniques can lead to considerable point loads on the pipe from stones and other materials. These loads on the outside of the pipe impose a high tensile stress on the bore of the pipe, which can lead to cracking and ultimately to failure.

To cope with these loading conditions high stress crack resistant materials are required, which is exactly why BorSafe™ HE3490-LS-H was created. This material will resist these additional stresses and ensure that the durability of the pipe is maintained.

**Increasing use of trench-less installation techniques**
Based on the success of the early “slip lining” projects many different “no dig” installation technologies were developed to meet different conditions. These techniques provide the system owner with a “new” pipeline at significantly lower costs and reduce the environmental impact compared to normal replacement methods.

However these techniques can give rise to a high level of scratching and scoring of the outside of the pipe which can lead to crack growth and ultimately to failure. This is particularly so when techniques such as “pipe bursting” are used, where the old cast iron, steel or other pipe is burst by an expanding hydraulic mandrel and an oversized PE pipe is pulled through the hole that is created. However, even if the damage is severe BorSafe HE3490-LS-H will resist the development and growth of a crack and ensure that the durability of the pipe will be maintained.

**Trenching in rocky terrain**

![Trenching in rocky terrain](image)

**Pipe outer surface after burst lining**

![Pipe outer surface after burst lining](image)
The importance of slow crack growth resistance

If, during installation, the pipe surface is heavily scored or notched there is a danger that under service conditions of pressure and soil loading this notch may develop into a sharp crack which then grows through the wall of the pipe and causes premature failure. The progress of the crack is inhibited by the structure of the polymer and in particular the number and strength of the tie molecules. The Borstar bimodal process has enabled us to develop a polymer with an extremely high resistance to crack growth, which will resist the development and growth of a crack from the scores and notches developed during installation and thereby maintain the design life of the pipe. Indeed, BorSafe HE3490-LS-H provides a step improvement in performance compared to standard PE100 materials.

Measuring the slow crack growth resistance

There are many different ways of measuring the slow crack growth resistance of different polyethylene materials. The most well known is the notched pipe test (NPT), which is specified in the International Standards for gas and water pipes (ISO 4437 & ISO 4427).

The NPT test works well with the older unimodal PE materials, but for the new bimodal grades the test times tend to be long (usually in excess of 1000 hours) and for high stress crack resistant materials like BorSafe HE3490-LS-H the test times can be over two years.

In Germany, DVGW has developed a new specification called PAS 1075, which is particularly relevant for pipe installation in rocky terrain and using alternative installation methods. Within this specification they describe the point load test (PLT) in which the PE pipe is pressurised and subjected to a constant level of indentation using a piston. Elevated temperature and an aqueous wetting agent are used to accelerate stress cracking. In order to qualify as a high stress crack resistant material suitable for alternative installation methods, such as directional drilling and pipe bursting, the material in pipe form is required to pass 8760 hours without failure, which is claimed to be equivalent to 100 years operation at 20°C in water. Even under these severe conditions BorSafe HE3490-LS-H outperforms this requirement by a large margin (see graph).

For regular quality testing of pipes the DVGW allow a Full Notch Creep Test (FNCT) to ISO 16770 to be used, the results of which have been correlated against the Point Load Test. A shorter form of FNCT test, the ACT is also allowed. As shown in the graph BorSafe HE3490-LS-H also exceeds the performance requirements of these tests.

BorSafe high stress crack resistant materials provide protection against crack growth of rocky backfill materials or “no dig” installation techniques. It allows the installer to benefit from the cost savings by using these techniques whilst providing the network owner and operator with “peace of mind”.

![Graph showing life hours vs. test methods](image-url)
High Stress Crack Materials in Action

Directional Drilling in Tianjin Eco – City
The Tianjin Eco – City is a joint development between the Chinese and Singapore governments. During its construction there was an urgent need to bring additional water to the area.

The Tianjin TEDA Water Company were keen to use PE100 for the complete pipeline due to the increased speed of installation, however they were concerned about the damage that could be caused by the directional drilling operation under the Ji Canal. To allay their concerns the contractor used pipe manufactured from high stress crack resistant material BorSafe HE3490-LS-H for this section, which provided the highest resistance to any surface damage that could have been induced during the installation.

Relining water injection pipelines for Kuwait Oil Company
Internal corrosion of steel pipe is a major problem for many oil companies, especially those with older wells, where there are high levels of hydrogen sulphide. An alternative to regular replacement is to use “close-fit” internal lining using PE which will extend the life of the pipeline.

The Kuwait Oil Company chose to test this option and for higher security specified high stress crack resistant BorSafe HE3490-LS-H. The PE pipe lengths were welded and pressure tested and then inserted into the steel pipe using the “Swagelining” technique. The lined section of pipe was then put back into service so that the performance could be monitored and compared to unlined sections.

Relining water pipes in Shanghai
In Shanghai over 16,000 km of iron pipe has been installed in recent times, but leakage rates are around 25% and in some areas the water quality is poor due to the internal corrosion of the iron pipes. The solution is to use PE100 pipes to line the old corroded water mains but there was concern about potential surface damage to the liner and therefore BorSafe HE3490-LS-H was specified.

A demonstration project was undertaken to line a corroded iron pipe with a 300mm diameter high stress crack resistant PE100 pipe using the “Swagelining” technique. The success of the project clearly demonstrated the potential value of the combination of No-Dig technology and the new high stress crack material in helping to solve China’s water problems.

Laying pipes in rocky soil in Afghanistan
A new PE water pipeline was required to link the city of Puli-khumri high in the Hindu Kush Mountains of Northern Afghanistan with a reservoir. The population of the city had grown rapidly to over 60,000 and an additional source of water was essential in this area which is prone to severe droughts.

As the area was extremely remote the pipeline had to be laid in the rocky ground without imported backfill and the German consulting engineers needed reassurance that the lifetime of this pipeline pipeline would not be prejudiced. The solution was to produce the 180 and 250mm SDR11 pipes from high stress crack resistant BorSafe HE3490-LS-H.
Borouge High Stress Crack Resistant PE100 Grades

<table>
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<th>Commercial Reference</th>
<th>Material Type</th>
<th>Colour</th>
<th>Application</th>
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<tbody>
<tr>
<td>BorSafe HE3490-LS-H</td>
<td>PE100</td>
<td>Black</td>
<td>Extrusion or co-extrusion of pipes for demanding conditions</td>
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<tr>
<td>BorSafe HE3492-LS-H</td>
<td>PE100</td>
<td>Yellow-orange</td>
<td>Extrusion or co-extrusion of gas pipes for demanding conditions</td>
</tr>
<tr>
<td>BorSafe HE3494-LS-H</td>
<td>PE100</td>
<td>Dark Blue</td>
<td>Extrusion or co-extrusion of water pipes for demanding conditions</td>
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</tbody>
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Overall benefits using BorSafe HE3490-LS-H, HE3492-LS-H and HE3494-LS-H

The main benefits of using high stress crack materials are as follows:
- The performance of a PE100 material meeting all the requirements of EN1555/ISO 4437 and EN12201/ISO 4427
- Additional security against crack growth meeting all the requirements of PAS 1075
- Exceptional resistance to slow crack growth to give a long lifetime
- Retains good low sag properties necessary for large diameter pipe production
- Ideal for custom design multilayer pipe to meet the demands of the installation technique
- Maintains the high security and high durability expected of PE systems
- Provides "Peace of Mind" for the project engineer/system owner

Some useful web sites and references

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<td>Borouge</td>
<td><a href="http://www.borouge.com">www.borouge.com</a></td>
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<td>Borealis</td>
<td><a href="http://www.borealisgroup.com/pipes">www.borealisgroup.com/pipes</a></td>
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<td>McGoldrick, J et al. Wiesbadener Kunststoffrohrtage, 2007</td>
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Borouge is a leading provider of innovative, value creating plastics solutions. A joint venture between the Abu Dhabi National Oil Company (ADNOC), one of the world’s major oil and gas companies, and Austria based Borealis, a leading provider of chemical and innovative plastics solutions, Borouge is a groundbreaking international partnership at the forefront of the next generation of plastics innovation.

Borouge has its headquarters in the United Arab Emirates and Singapore, employs approximately 1,600 people representing more than 40 nationalities and serves customers in more than 50 countries across the Middle East, Asia-Pacific, Indian sub-continent and Africa. Building on Borealis’ unique Borstar® technology and experience in polyolefins for more than 50 years, Borouge provides innovative, value creating plastics solutions for the infrastructure (pipe systems, and power and communication cables), automotive and advanced packaging markets.

In 2010 Borouge tripled its annual production capacity in Abu Dhabi to 2 million tonnes and an additional 2.5 million tonnes per year will be introduced by mid-2014 to create the world’s largest integrated polyolefins plant. Borouge is also investing in plants and logistics hubs in Asia and an Innovation Centre in Abu Dhabi. Today Borouge and Borealis have a manufacturing capacity of over 5.4 million tonnes of polyethylene and polypropylene annually. Focused on Value Creation through Innovation they ensure that their customers throughout the value chain, around the world, can always rely on superior products and security of supply.

Borouge is committed to the principles of Responsible Care® and together with Borealis proactively contributes towards addressing the world’s water and sanitation challenges through their Water for the World™ initiative.

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