VESTAMID® NRG

NON-METALLIC APPLICATIONS
BEYOND THE WELL

VESTAMID® NRG
FOR GAS DISTRIBUTION

EVONIK
POWER TO CREATE

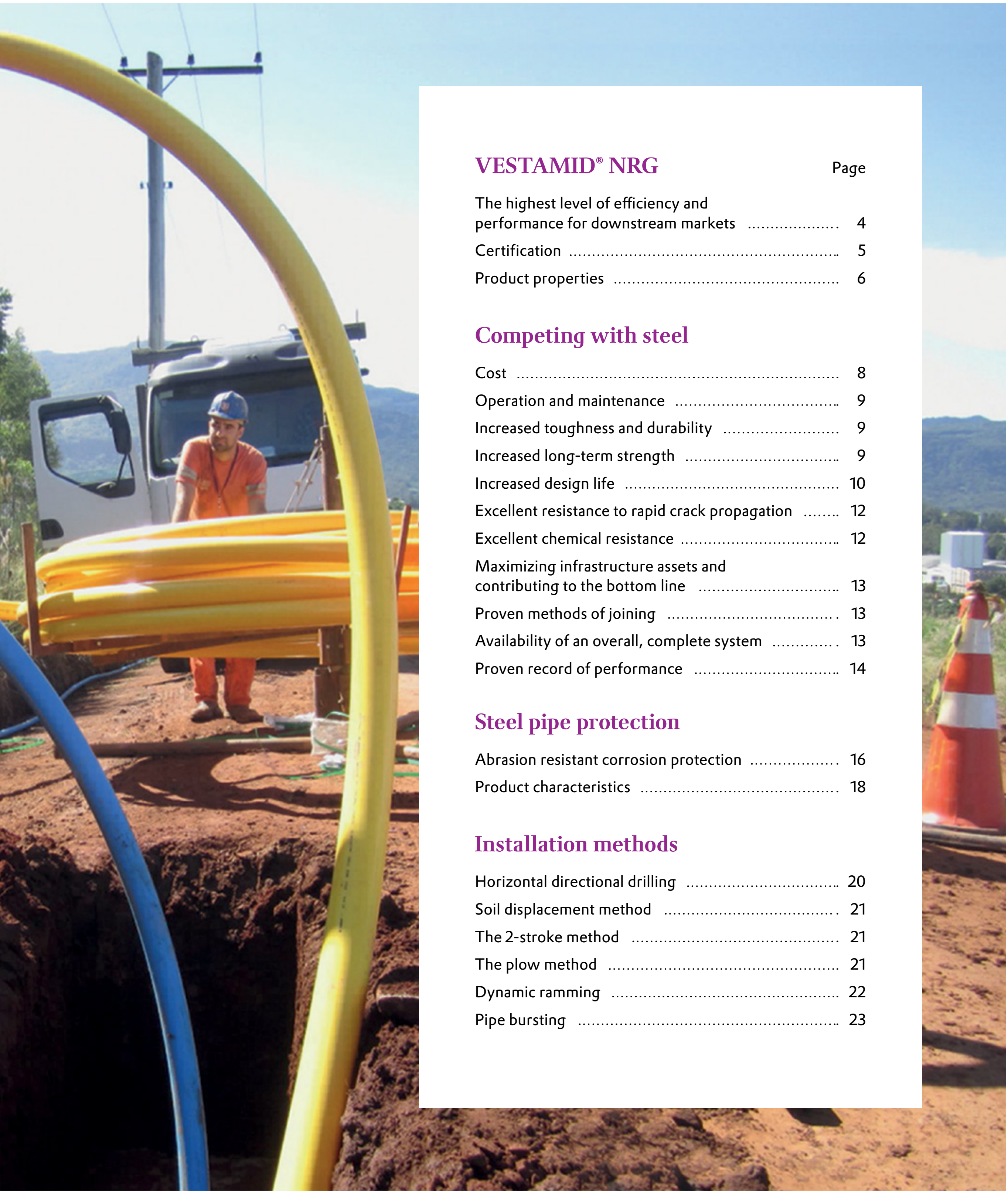
INTRODUCTION

German-based Evonik Industries is one of the world's leaders in specialty chemicals. Evonik's high-performance polymers are suitable for a virtually unlimited range of uses, including a particularly large number of applications in the energy sector.

Depending on the application, these polymers provide protection against corrosion or chemicals, increase the safety of energy transport, or enhance the efficiency of energy generation or gas separation.

VESTAMID® NRG is a polyamide 12 product specifically developed for energy-efficient oil and gas pipelines.

Evonik. Power to create.



VESTAMID® NRG

Competing with steel

Steel pipe protection

Installation methods

THE HIGHEST LEVEL OF EFFICIENCY AND PERFORMANCE FOR DOWNSTREAM MARKETS

For many years, steel was the only material available for gas piping for pressures ranging between 10 and 18 bar. Steel had no competition until the arrival of VESTAMID® NRG, a polyamide 12 (PA 12) product. This material withstands operating pressures of up to 16 bar, making it suitable for distribution lines and industrial connections. Fittings and end caps are made of the same material.

■ VESTAMID® NRG

For over 50 years, PA 12 has been established for use in safety-related automobile components, and can be found in the fuel lines, air-brake lines, and hydraulic lines of vehicles from virtually all renowned automakers. Its considerable chemical resistance and outstanding mechanical properties make PA 12 the ideal material for components that come into contact with hydrocarbon-containing media—and that includes gas pipes.

Thanks to VESTAMID® NRG 2101, Evonik has successfully developed PA 12 molding compounds that meet the requirements of large-volume gas piping:

- Gas resistance and impermeability
- Pressure and aging stability
- Mechanical strength and durability
- Extremely well resistance against slow crack propagation
- Highly resistant to damage at the construction site or during installation
- Can be laid without sand bedding
- Suitable for horizontal directional drilling

Certification

Pipes made of VESTAMID® NRG 2101 have undergone all of the usual tests for pressurized gas lines standardized both in the ISO 16486 series for raw materials, piping, molded components, valves, and suitability for use, as well as in guidelines for planning, handling, and installing PA12.

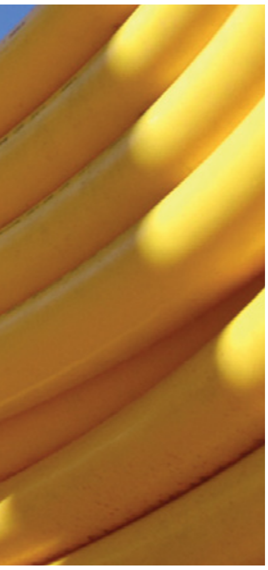
In Germany, the requirements and testing for PA12 are also defined in Test Specification GW 335-A6 published by the German Technical and Scientific Association for Gas and Water (DVGW). NRG 2101 has been certified according to ISO 16486-1 and DVGW GW 335-A6.

EXCELLENT PRODUCT PROPERTIES MEETING THE REQUIREMENTS OF GAS PIPING

A – PIPE AND FITTINGS DATA SHEET

PROPERTIES		Unit	Test procedure	VESTAMID® NRG 2101 yellow
General properties	Material designation		PPI TR-4	PA12
	Cell classification		ASTM D3350	PA423
	Density at 73°F resp 23°C	g/cm³	ISO 1183	1.02
Pipe properties	Hydrostatic design basis at 73°F (23°C)	psi	ASTM D2837	3,150
	Hydrostatic design basis at 140°F (60°C)	psi	ASTM D2837	2,000
	Minimum required strength	MPa/psi	ISO 9080	18/261
	Rapid Crack Propagation critical pressure (PC), 32°F (0°C)	bar/psig	ISO 13478	30/435
	Pipe test category	----	ASTM D2513	
Material properties	Tensile stress at yield	MPa/psi	ISO 527/ASTM D638	39/5,760
	Strain at break	%	ISO 527/ASTM D638	>200
	Tensile modulus	MPa	ISO 527	1,300
	PENT (2.4 MPa)	h	ASTM F1473	>2,000 hours
	PENT (4.8 MPa)[1]	h	----	>2,000 hours
	Moisture absorption 74°F resp. 23°C/50% r.h.	%	ISO 62	0.8
	Water absorption (saturation)	%	ISO 62	1.5
Thermal properties	Melting temperature DSC 2nd heating	°C/°F	ISO 11357	177/350
	Vicat softening temperature – Method A – 10N	°C/°F	ISO 306	176/349
	Vicat softening temperature – Method B – 50N	°C/°F	ISO 306	150/302

[1] Test specimen and overall test methodology is same as ASTM F1473 but at increased stress levels



B – PHYSICAL DATA

Material Properties		Standard	Specimen	Requirement	Unit	VESTAMID® NRG 2101 yellow
Melting point		ISO 3146, ISO 11357	granules	170 -195	°C/°F	177/350
Heat of fusion		ISO 3146, ISO 11357	granules	---	J/g	65
Glass transition temperature		ISO 3146, ISO 11357	granules	---	°C/°F	36/97
Heat capacity DSC		ISO 3146, ISO 11357	granules	---	J/(g•K)	2.02
Thermal expansion coefficient		ISO 11359	2″ SDR11	---	µm/(m•K)	144
Thermal conductivity coefficient		ASTM C177		---	W/(m•K)	0.25
	Method A – 10N	ISO 306	derived from ISO 527/1A	---	°C/°F	170/338
Vicat softening temperature	Method B – 50N	ISO 306	derived from ISO 527/1A	---	°C/°F	150/302
	HDT A – 1.80 MPa	ASTM D648	derived from ISO 527/1A	---	°C/°F	45/113
Heat distortion temperature	HDT B – 0.45 MPa	ASTM D648	derived from ISO 527/1A	---	°C/°F	145/293
Longitudinal reversion		ISO 2505	2″ SDR11	max. 3	%	0.33

COMPETING WITH STEEL

For years another polymer, polyethylene (PE), is used successfully for pipes at low pressures until 10 bar maximum. In contrast, until now only steel has been applied at pressures higher than 10 bar.

Like PE, VESTAMID® NRG 2101 piping systems offer a superior range of economic benefits for gas utility companies as compared to metal piping.

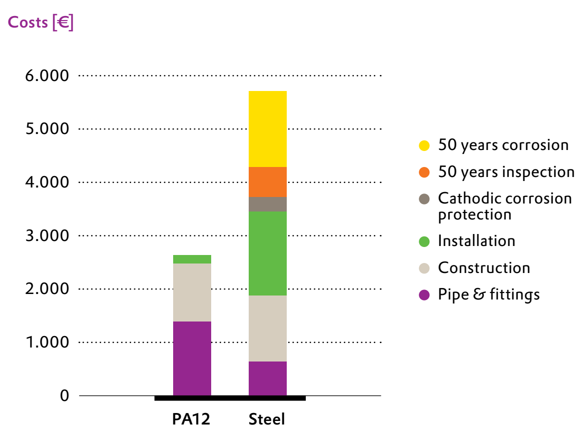
PA12 piping systems feature well-known advantages during installation, maintenance, and operation. The following have made the investment worthwhile for a number of gas companies:

- VESTAMID® NRG pipe is lightweight and easier to handle and transport.
- Given their inherent flexibility, VESTAMID® NRG pipes can be delivered in coils, thereby reducing the number of joints to create in the field, increasing productivity, and reducing installation costs.
- Pipes and fittings can be joined by butt fusion and electro-fusion, thus reducing installation time and cost.
- VESTAMID® NRG pipes can be used with an array of low-cost, trenchless rehabilitation techniques, including horizontal directional drilling, slip lining, pipe bursting, etc.
- Using these techniques more pipes can be installed in a shorter period than using conventional installation methods.
- VESTAMID NRG piping systems do not require expensive active or passive corrosion protection, thus significantly reducing investment and maintenance costs.
- VESTAMID® NRG retains its chemical, physical, and mechanical stability over its design life and does not experience premature oxidative degradation, circumferential expansion, or loss of long-term strength.

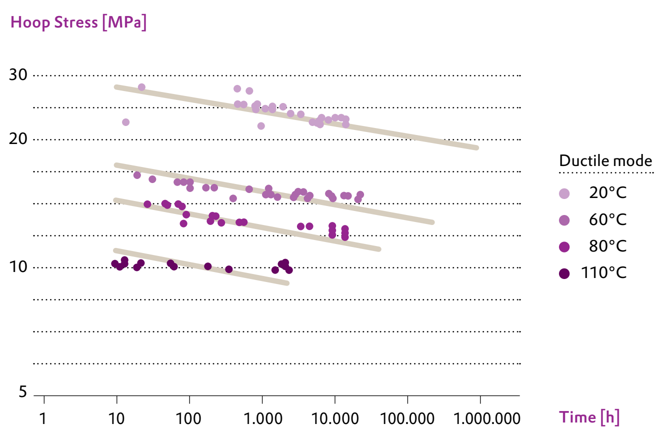
Cost

The advantages mentioned in the cost diagram are known to bring considerable economic and social benefits. The time required for installing a DN110, PN16 PA12 pipeline, for example, is more than 40% shorter than that required for installing an equivalent steel pipeline. The time that this saves has a direct social impact thanks to reduced traffic congestion, noise, and dust pollution. In additional, total installation costs for the pipeline described here are reduced by 40%. Finally, the cumulative reduction in maintenance costs over the 50-year nominal design lifetime yields great additional economic benefits to pipeline operators and their customers.

Cost comparision



ISO 9080 graph VESTAMID® NRG 2101



Operation and maintenance

VESTAMID® NRG PA12 has been used for a decade in various natural gas distribution networks around the world. This system has huge advantages during operation. PA12 does not corrode, and therefore does not require any corrosion prevention or maintenance. The impact resistance of PA12 is extremely high, increasing safety, as practical excavator tests have shown.

▶ VIDEO

Nevertheless, downstream emergency shutdowns can occur. In the event that valves have not been installed, squeeze off is a well-known procedure for maintenance operations. Together with other industrial partners and external institutes, Evonik conducted an extensive study on squeeze-off, re-rounding, and double block-and-bleed methods. The study showed that PA12 gas pipes squeezed at their operating pressure (16 bar for PA12) exhibited the lowest leakage rate of all of the materials investigated. The double block-and-bleed configuration is another option for safely shutting down piping with no leaks, thus allowing safe maintenance work downstream.

Today's infrastructure is planned in an intelligent way, and this is expected to continue with the growing needs of residential and industrial areas. Operators recognized one additional advantage: the use of hot tapping allowed them to extend PA12 natural gas networks without interrupting network operation. Special electrofusion fittings have been developed for this method and are available in a variety of sizes.

Increased toughness and durability

Extensive research data and actual field performance validate the overall toughness and durability of VESTAMID® NRG PA12. Experience has shown that VESTAMID® NRG 2101 retains its toughness and durability over a wide range of installation conditions, including higher temperatures, excessive bending strains, and highly compressive and/or contaminated soils. Most importantly, the increased toughness and durability of VESTAMID® NRG 2101 allows it to withstand the potential impact of third-party damage better than most thermoplastic materials used today.

Increased long-term strength

Both ASTM and ISO have established protocols to characterize the long-term strength of thermoplastic pipes used in gas distribution applications. VESTAMID® NRG 2101 has a higher hydrostatic design basis (HDB) and a higher minimum required strength (MRS) than other thermoplastic materials, and this gives operators greater flexibility in their overall design approach as they seek to satisfy capacity considerations.

For more information please follow this link:

HTTPS://PLASTICPIPE.ORG/PUBLICATIONS/TECHNICAL-REPORTS.HTML

C – LONGTERM MECHANICAL PROPERTIES

Material properties	Standard	Specimen	Unit	VESTAMID® NRG 2101 yellow
LPL	ISO 9080	2″ SDR11	MPa	19.04
MRS	ISO 12162	2″ SDR11	MPa	18
HDB 73°F	ASTM D2813	2″ SDR11	psi	3,150
HDB 140°F	ASTM D2813	2″ SDR11	psi	2,000
HDB 180°F	ASTM D2813	2″ SDR11	psi	1,600

MOP (bar) = (MRS * 20) / (2 * (SDR-1))
MOP (psi) = ((HDB * 2) / (SDR – 1)) * 0,4

MOP = Maximum Operating Pressure
MRS = Minimum Required Strength
SDR = Standard Dimension Ratio
HDB = Hydrostatic Design Basis
LPL = Lower Prediction Limit

■ Increased design life

Over 40 years of field experience with PE piping systems have demonstrated that slow crack growth (SCG) is one of the leading causes of field failures with plastic piping systems. SCG is the result of various factors, including improper manufacturing or installation practices (such as squeeze-off, excessive bending strain, poor fusion alignment, etc.) and environmental factors such as rocky soils or point loads. (Table D)

To ensure the safety of plastic piping materials and to protect them from SCG failures, both ASTM and ISO standards have incorporated performance-based requirements and tests, including the Pennsylvania notch test (PENT) and the notch pipe test.

Evonik has performed extensive testing on VESTAMID® NRG 2101, and the results validate its superior SCG resistance characteristics and its greater long-term performance. Compared to other thermoplastic materials, VESTAMID® NRG 2101 performs extremely well under the PENT test. To illustrate, VESTAMID® NRG 2101 did not fail even after undergoing the PENT test for 2,000 hours at a stress of 4.8 MPa—two times greater than the current test requirements stipulated in ASTM F1473.

In addition to its performance on the PENT test, VESTAMID® NRG 2101 also exhibits excellent resistance to surface scratches and notches. In comprehensive tests meeting ISO requirements, VESTAMID® NRG 2101 pipe materials with a 30 percent notch did not fail after 1,000 hours at a test pressure of 20 bar and a temperature of 80°C (290 psig at 176°F).

Most importantly, the results of extensive testing have shown that VESTAMID® NRG 2101 does an excellent job of resisting persistent point loads from rocks or other hard objects in the backfill material. In tests performed at the Hessel Institute, VESTAMID® NRG 2101 showed NO failures at 31 bar and 60°C (450 psig at 140°F) under the combined effects of internal pressure and point load. The results confirm that VESTAMID® NRG 2101 can be used safely with no need for additional backfill or sand bedding. (Table E)

Cumulatively, the results show that VESTAMID® NRG 2101 material has ample strength and toughness to resist failure due to slow crack growth under various types of in-service stress—and this, in turn, leads to longer design lifetimes.

1

NO PENT FAILURES

at 4.8 MPa
for over 2,000 hours

D – LONGTERM MECHANICAL PROPERTIES

Material properties	Standard	Specimen	Requirement	Unit	VESTAMID® NRG
SCG, GTI	ISO 22621 / 13478	2″ SDR11	min. 500	h	>2,000
SCG, Gastec	ISO 22621 / 13479	110 mm SDR11	min. 500	h	> 810
PENT test, GTI	ASTM D2513 / F1743	Plaque	min. 500	h	>1,000
Squeeze-off, GTI	ASTM D2513 / ISO 22621	2″ SDR11	min. 500	h	>1,000
Rock impingement	GTI Method / ISO 22621	2″ SDR11	min. 500	h	>1,000
Earth loading	GTI Method / ISO 22621	2″ SDR11	min. 500	h	>1,000
Bending strain	GTI Method / ISO 22621	2″ SDR11	min. 500	h	>1,000

E – LONGTERM MECHANICAL PROPERTIES

Secondary stress	Test criterion	Test pressure	Hoop stress	Test Temperature	Results
Point load		31 bar/450 psig	14.75 N/mm^2	60°C/140°F	Test time >22,500 hours with no failures
Point load	3 mm inside notch	31 bar/450 psig	10 N/mm^2	80°C/140°F	Crack growth after 10,939 hours
Rock impingement	1,3 cm/0,5″ indentation	20 bar/290 psig		80°C/176°F	Test time >1,000 hours with no failures
Earth loading	5% deflection of outside diameter	20 bar/290 psig		80°C/176°F	Test time >1,000 hours with no failures
Bending strain	20 times OD	20 bar/290 psig		80°C/176°F	Test time >1,000 hours with no failures

NO FAILURES

at 20 bar and 80°C (290 psig and 176°F) with a 20 percent NOTCH for over 1,000 hours

NO FAILURES

at 20 bar and 80°C (290 psig and 176°F) with a 30 percent NOTCH for over 1,000 hours

NO FAILURES

for 3/6 test specimens at 20 bar and 80°C (290 psig and 176°F) with a 50 percent NOTCH for over 1,000 hours

COMPETING WITH STEEL

Excellent resistance to rapid crack propagation

The results of comprehensive testing have demonstrated that VESTAMID® NRG 2101 material does an excellent job of resisting failures from rapid crack propagation (RCP).

While actual RCP failures are rare, all materials are susceptible under the right set of conditions. To ensure that only those materials with ample resistance to RCP failures are used for gas distribution applications, both ASTM and ISO standards require a series of tests, including the small-scale steady state (S4) test and the full-scale test (FST). The FST test is considered to be the reference test.

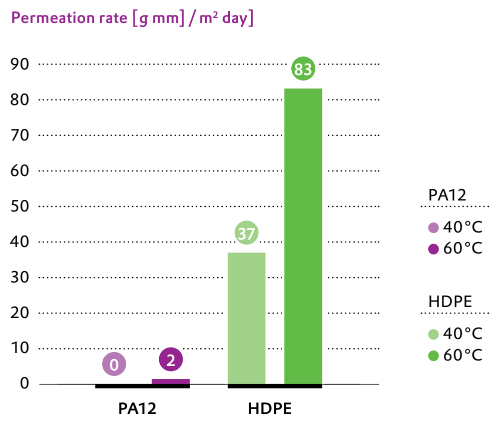
The results of full-scale RCP tests confirm the excellent RCP resistance of VESTAMID® NRG 2101 over a range of increased operating pressures.

RCP RESULTS OF FULL SCALE TEST*

	Pipe size	P Critical at 0°C/32°F
SDR 11 pipe	110 mm	Pc,fs ≥ 30 bar/435 psig
SDR 11 pipe	6-inch IPS	Pc,fs ≥ 25 bar/362 psig

* in accordance to ISO 13477

Permeation of a benzene, toluene, and xylene mixture (BTX) through PA12 and HDPE



Excellent chemical resistance

A unique benefit of the inherent molecular make-up of VESTAMID® NRG PA12 molding compounds is that they are extremely resistant to heavy hydrocarbons, making them ideal candidate materials for extremely harsh environmental conditions. As a result, VESTAMID® NRG PA12 material is the perfect choice where the soils have been contaminated due to gasoline spills, etc. Plus, it is also highly resistant to odorizing chemicals and serves as an outstanding barrier to the hydrocarbons found in gas condensates (benzene, toluene, and xylene – BTX).

F – CHEMICAL RESISTANCE

			Change in weight (%)		Change in tensile strength at yield (%)	
Material properties	Standard	Specimen	Requirements	Results	Requirements	Results
Control	ASTM D2513-06	split ring	---	---	---	---
Mineral oil	ASTM D2513-06	split ring	< 0.5	0	max. -12	1
Toluene in methanol	ASTM D2513-06	split ring	< 7.0	2.8	max. -40	-12
Methanol	ASTM D2513-06	split ring	< 5.0	2.5	max. -35	-20
Ethylene glycol	ASTM D2513-06	split ring	< 0.5	0	max. -12	-5
Tertiary butyl mercaptan	ASTM D2513-06	split ring	< 0.5	0	max. -12	-10

Maximizing infrastructure assets and contributing to the bottom line

Given their superior performance characteristics, VESTAMID® NRG PA12 piping systems offer significant economic benefits compared to other types of piping systems available in the marketplace.

Proven methods of joining

The overall integrity and longevity of any piping system is predicated on its weakest link. In the case of metallic piping systems, this has been joints where mechanical fittings or gaskets are used that tend to corrode or leak over the life-time of the pipeline.

VESTAMID® NRG 2101 piping systems can be contructed using proven butt heat fusion or electrofusion joining methods. It has been proven that joints made using either of these two methods are stronger than the actual pipe, thus enhancing the overall integrity of the pipeline. These methods do not require additional capital investment since conventional tools used with PE piping systems can be readily used here as well. In other words, there is no need for special butt fusion equipment or electrofusion boxes when joining VESTAMID® NRG 2101 pipe segments. This allows for seamless and transparent integration within gas utility companies' operations.

Availability of an overall, complete system

Evonik has partnered with leading gas component manufacturers to offer a complete line of piping and fittings conforming to the strictest ASTM and ISO product specifications. This enables gas utility companies to effectively design, construct, and maintain VESTAMID® NRG 2101 piping systems capable of lasting a long time with worry-free service. Transition fittings and risers conforming to ASTM F1973 are available for tying in to existing steel assets. Electrofusion couplings and saddles conforming to ASTM F2767 are also available for connecting PA12 piping segments and extending lateral connections.

G – BUTT FUSION JOINTS

Material properties	Standard	Specimen	Ambient temperature at fusion	Requirement	Unit	VESTAMID® NRG 2101 yellow
Hydrostatic strength	ISO 22621 / 1167	110 mm SDR11	0°C/ 32°F	min. 165	h	>165
Hydrostatic strength	ISO 22621 / 1167	110 mm SDR11	23°C/ 73°F	min. 165	h	>165
Hydrostatic strength	ISO 22621 / 1167	110 mm SDR11	40°C/104°F	min. 165	h	>165

■ Proven record of performance

VESTAMID® NRG 2101 piping systems have been extensively tested under actual field conditions over a range of pipe sizes, intended operating pressures, and installation environments. The results provide unequivocal proof that VESTAMID® NRG 2101 piping systems provide peace of mind and a valuable alternative to metallic piping.

OVERVIEW OF THE GLOBAL INSTALLATIOS WITH VESTAMID® NRG PIPES

Location	Date		Dimension		Pressure
Gas Technology Institute (GTI), Des Moines, Illinois, USA	Feb	2005	2"	SDR 11	260 psig
E.ON Ruhrgas, Dorsten, Germany (Test installation)	2005 –	2007	110 mm	SDR 11	26 bar
E.ON Ruhrgas, Dorsten, Germany (Test installation)	2005 –	2007	110 mm	SDR 11	36 bar
Gas Technology Institute (GTI), Des Moines, Illinois, USA	Nov	2006	6"	SDR 11	260 psig
Gas Technology Institute (GTI), Des Moines, Illinois, USA	Nov	2006	6"	SDR 11	260 psig
National Fuel Buffalo, New York, USA	Nov	2006	6"	SDR 11	260 psig
City of Mesa, Mesa, Arizona, USA	March	2008	4"	SDR 11	140 psig
DTE MichCon Detroit, Michigan, USA	May	2008	4"	SDR 11	330 psig
WE-Energy Racine, Wisconsin, USA	May	2008	4"	SDR 11	260 psig
Energy West, Montana, USA	July	2009	4"	SDR 13,6	176 psig
Energy West, Atmos, Mississippi, USA	Aug	2009	6"	SDR 13,6	176 psig
	Aug	2012	4"	SDR 13,6	125-250 psig
Energy West, Montana, USA	Aug	2012	1″	SDR 11	125-250 psig
MSGas, Campo Grande, Brazil	Oct	2012	90 mm	SDR 11	17 bar
SulGas, Sapiranga, Brazil	March	2013	90 mm	SDR 11	15 bar
DTE Ohio, Ohio, USA	Aug	2014	4"	SDR 11	200 psig
GdF Suez, Mexico City, Mexico	Sep	2014	90 mm	SDR 11	14 bar
PGN, Semarang, Indonesia	Nov	2014	160 mm	SDR 11	16 bar
Evonik Biolys, Castro, Brazil	May	2015	110 mm	SDR 11	4 bar
MSGas, Campo Grande, Brazil	Nov	2015	160 mm	SDR 11	16 bar
SurtiGas, Tierrabomba, Colombia	June	2016	160 mm	SDR 11	16 bar
EHK, Indonesia	Dec	2016	110mm	SDR 11	16 bar
CEGAS, Brazil	Jan	2017	160mm	SDR 11	16 bar
Westnetz/Innogy/RWE, Germany	July	2017	160 mm	SDR 11	16 bar

Since late 2016, a 4.6 km underwater VESTAMID® NRG pipeline has been supplying the inhabitants of Tierra Bomba, an island off Colombia's Caribbean coast, with natural gas.

STEEL PIPE PROTECTION

ABRASION RESISTANT CORROSION PROTECTION

With its high-end application capabilities, VESTAMID® NRG offers a flexible, mechanically tough encasement system that combines the advantages of polyethylene and glass fiber reinforced plastic coating.

■ **Advantages of VESTAMID® NRG as encasement material**

- Unusually high impact resistance and toughness, even at low temperatures
- Excellent stress cracking resistance
- Excellent wear resistance
- Low sliding friction coefficient

STEEL PIPE PROTECTION

Product characteristics compared with other encasement materials

VESTAMID® NRG has higher Shore hardness than polyethylene (PE) or polypropylene (PP). In contrast to PE or PP encasement, therefore, the polyamide encasement offers both the corrosion protection provided by the barrier effect and mechanical protection for the encased steel pipe.

Application areas for the new encasement material use non-conventional installation techniques such as:

- horizontal directional drilling
- the soil displacement method with non-steered displacement hammers
- dynamic ramming
- plow technology

VESTAMID® NRG is applied on the surface of the steel pipe by the established extrusion methods used for PE or PP application. Preliminary tests and pilot projects have yielded impressive evidence of the performance of VESTAMID® NRG. It was already clear in the preliminary tests that, due to its greater hardness, VESTAMID® NRG encasement showed, as expected, hardly any scoring, while pipe insertion with polypropylene encasement leaves clear tracks.

In trenchless installation it must be ensured that the coating of the steel pipe is not damaged. Using the cathodic corrosion protection method, it was successfully demonstrated in the pilot projects that the PA12 casings were not in any way damaged during the installation process.

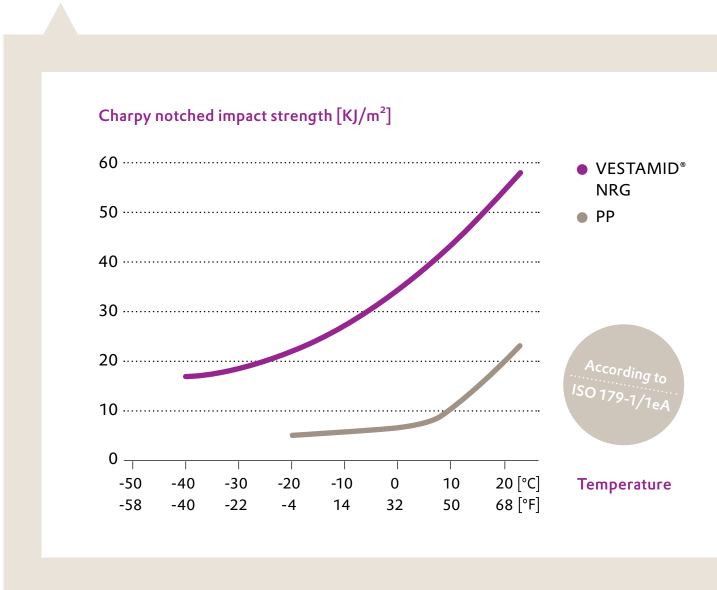
An initial pilot project for HDD installation was carried out in Algermissen (Germany): A 300 m run of pipe was laid under a canal for E.ON Avacon. No significant damage to the VESTAMID® NRG layer was detected, either visually at the pipe section in the directional drilling borehole or by cathodic corrosion protection measurements.

In a further pilot project, the plow method was used over a 1.5 km run near Wallersdorf (Germany) on a commission from Wasserversorgung Bayrischer Wald (WBW).

Reeling is another example of applications of this type in off-shore technology. The pipes are welded onshore into a kilometer-long run, spooled onto large pipe reels, and later laid in a run on the high seas. In this installation technology, the steel tubes even show plastic deformation, a stress that the corrosion protection layer must also be capable of withstanding.

Notched impact strength

A comparison of notched impact strengths demonstrates the excellent properties of VESTAMID® NRG in relation to those of polypropylene, especially at low temperatures.



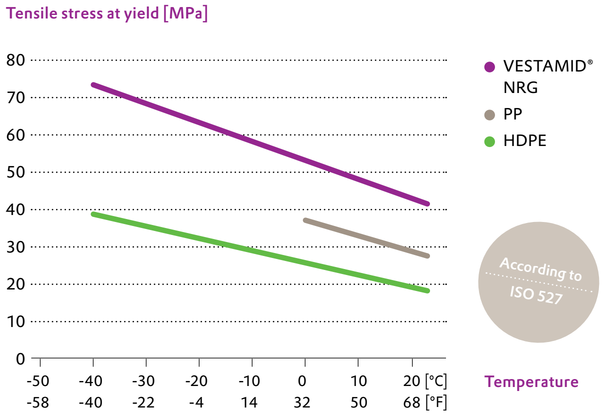
H – VESTAMID® NRG 4101 YELLOW AND NRG 4901 BLACK FOR HIGH PERFORMANCE STEEL PIPE PROTECTION

Material properties		Unit	Test method	Typical value
Density at 73°F resp. 23 °C		g/cm³	ISO 1183	1.02
		MPa	ISO 527	39
Tensile stress at yield		psi	ASTM D638	5,760
Strain at break		%	ISO 527 / ASTM D638	>200
Tensile modulus		MPa	ISO 527	1,300
Moisture absorption at 73°F resp. 23°C/50% r.h.		%	ISO 62	0.8
Water absorption (saturation)		%	ISO 62	1.5

Thermal properties				
		°F	ISO 11357	350
Melting temperature DSC 2nd heating		°C	ISO 11357	177
		°F	ISO 306	349
	Method A – 10N	°C	ISO 306	176
		°F	ISO 306	302
Vicat softening temperature	Method B – 50N	°C	ISO 306	150

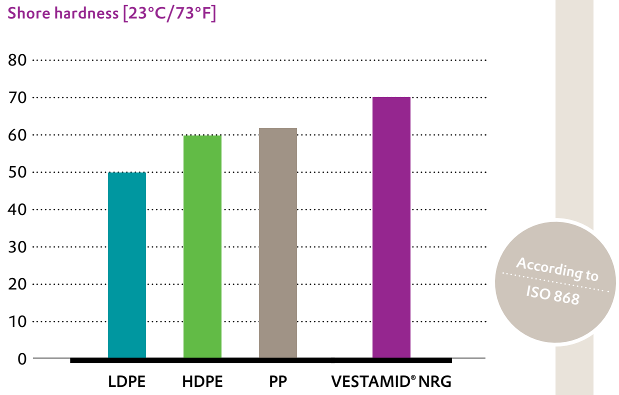
Tensile testing

The fact that this material is harder also shows in its strength values, such as stress at yield. Polypropylene, which is stronger than polyethylene, can only be used at temperatures down to 0°C/32°F.



Shore D hardness

VESTAMID® NRG has higher Shore hardness than polyethylene and polypropylene.



INSTALLATION METHODS

Horizontal directional drilling

Directional drilling has seen an enormous boom in recent years. Directional drilling operations that would have appeared inconceivable just a few years ago are now routinely performed at installation sites. Drilling is often carried out underneath and across rivers and other water bodies, and directional technology even allows drilling below industrial complexes. The application spectrum extends over all pipework for the supply of gas, district heating, and drinking water, and the installation of pressure lines for sewers.

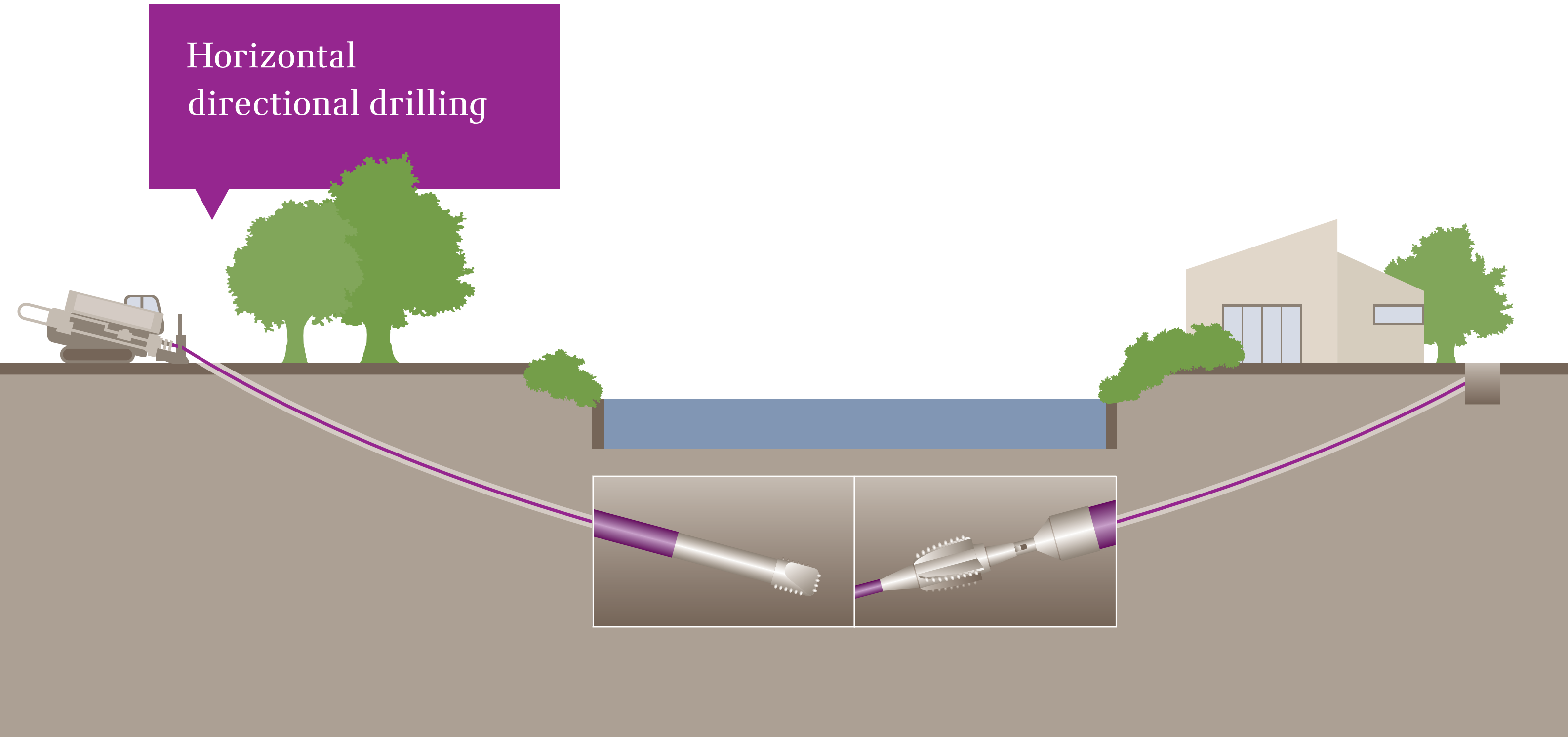
The installation technique is extremely eco-friendly, causing minimal ecological damage that is restricted to points in the immediate vicinity of the system. Many factors favor the use of directional technology even in urban areas: The technique scores over open-trench methods in terms of construction times and costs, licensing procedures, soil displacement, surface restoration, and traffic disruption.

The combination of fluid-assisted drilling with impact support allows propulsion and steerability in difficult soils (with large-particle components, fairly large rock inclusions, or building-rubble deposits) of soil class 5, and in some cases up to soil class 6.

The stringent requirements and expectations for the tasks to be accomplished demand precise location and steering of the drilling. For insertion of plastic pipes (particularly those carrying gas and drinking water) the pulling forces must not exceed the values specified in GW 321, 322, and 323. Horizontal directional drilling is described in GW 304 (Pipe Driving) and ATV-A 125 and the relevant regulations.

Advantages of the method

- No opening up of useful surfaces, no surface damage (to road surfacing, front gardens, etc.), and no restoration required; therefore strong economic advantages
- Low social costs by avoidance of diversions, closures of traffic lanes, setting up of signaling systems, etc.
- Short setup times, short installation and construction times
- Particularly cost-effective for river crossings
- Measurement of pulling force and determination of position are possible.
- Broad application spectrum



Soil displacement method with non-steered displacement hammers

The soil displacement method has been established for decades as a technique for underground pipe installation. A pneumatically operated displacement hammer creates an underground cavity into which are inserted short or long plastic or metal pipes up to DN 200, preferably without socket ends. The pipes are introduced in lengths of up to 40 m, depending on the soil, either simultaneously or in a second work step. This technique allows trenchless crossing of traffic routes, house service connections, preparation of anchoring, bypassing of obstacles, and other advantages.

The 2-stroke method

Depending on the soil, the soil displacement hammers attain a ramming speed of up to 15 m/h. The soil displacement method is described in ATV-A 125 and GW 304 (Pipe Driving), and other relevant regulations.

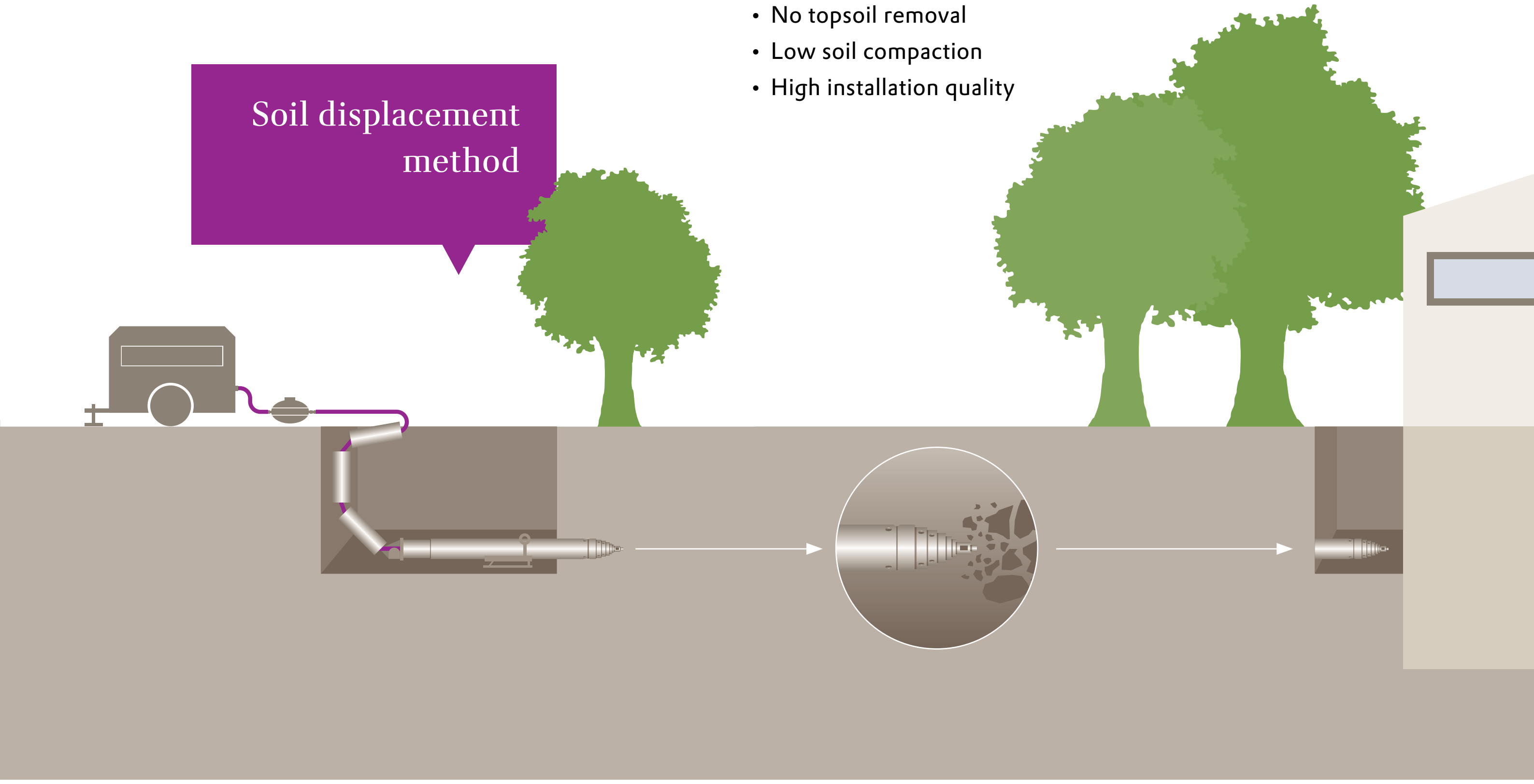
The plow method

Plow technology has been very successfully used since the 1970s for laying of power and phone lines. It is particularly suitable for large, open, cross-country stretches where long line lengths are necessary; however, plowing can also be used over shorter distances and for lines in less readily accessible areas. Installation of these lines in sloping ground and the crossing of water bodies (with water levels of up to 1.20 m) present no technical problems, thanks to the plow design with its four booms adjustable in any direction.

This method is particularly suitable for soil types that are easily displaced, but even large-particle soils with a high proportion of stone present no problems.

Advantages of the method

- Financial savings of up to 50 percent
- High daily capacity of up to 5,000 m possible
- Short setup and construction times
- Low HR costs
- Fuel consumption reduced by 90 percent
- Plowing and line installation in a single operation
- No groundwater lowering required
- Minimal traffic disruption
- Small working area
- No topsoil removal
- Low soil compaction
- High installation quality



Dynamic ramming with non-steered ramming machines

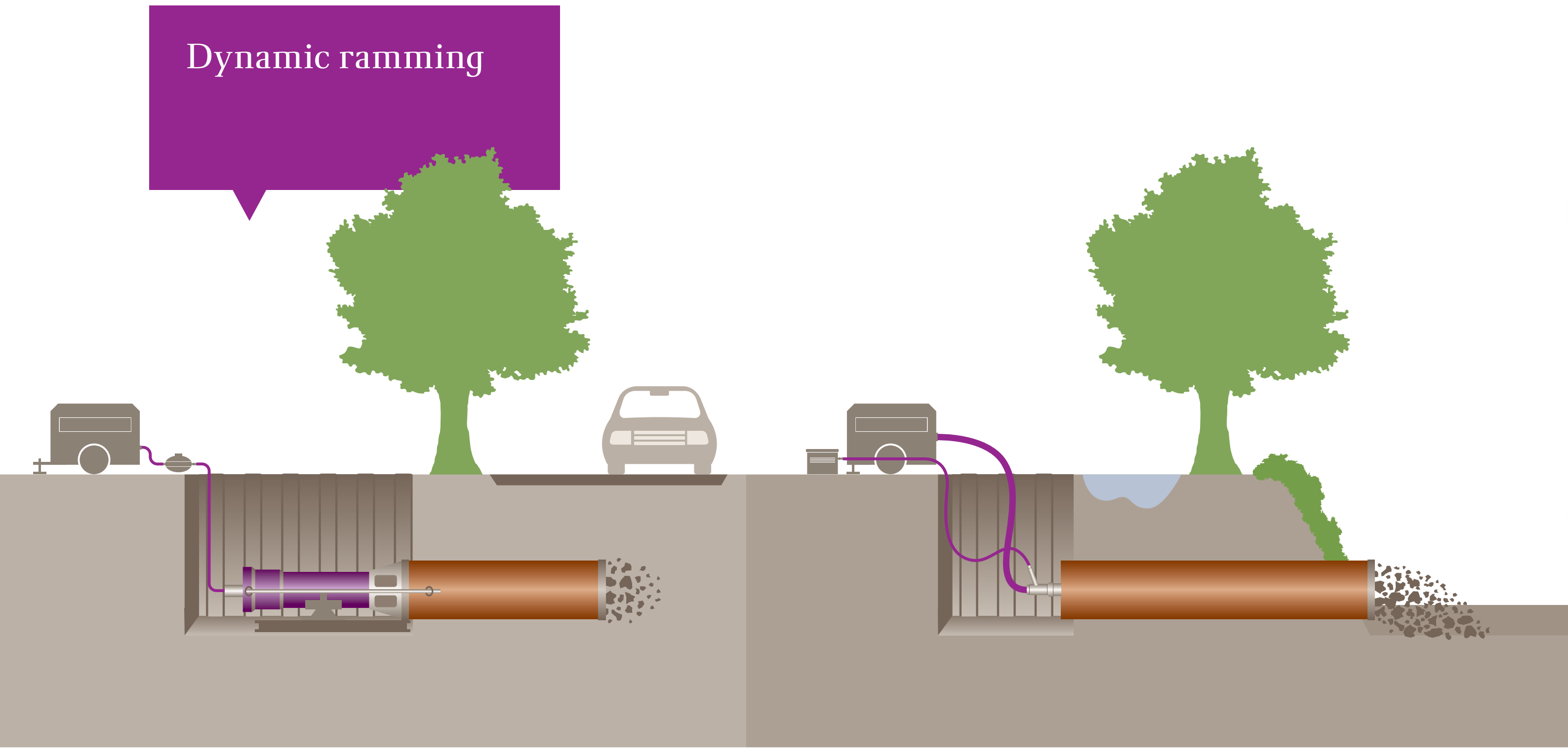
Dynamic pipe driving by the ramming method uses pneumatically operated pipe-driving machines. These allow installation of open steel pipes as casing or product pipes up to 4,000 mm in diameter over lengths of up to 80 m in soil classes 1-5 (and in some cases also in soil class 6, easily detachable rock) particularly cost effectively and without jacking abutments, under rail-road lines, expressways, and rivers.

Individual pipe lengths are pushed forward in succession after welding. Due to the robust one-piece construction, a large ram at full capacity can generate an impact energy of 40,000 Nm, optimally transferred over the entire pipe string to the front cutting edge. The average ramming speed is 10 m/h.

The ramming technique is described in ATV-A 125 and GW 304 (Pipe Driving) and the relevant regulations.

Advantages of the method

- Little opening up of useful surfaces, low surface damage (to road surfacing, front gardens, etc.), and little restoration, therefore strong cost advantages
- Low social costs by avoidance of diversions, closures of traffic lanes, setting up of signaling systems, etc.
- Short setup times, short installation times
- The soil core remains in the pipe during ramming, so there is no water penetration when rivers are crossed.
- Minimal cover, i.e., no large-scale trenches
- Broad application spectrum



Pipe bursting

The pipe bursting method is an approved technique which is applicable according to the latest generally accepted technical standards.

A pipe bursting machine is pulled through the old defective pipe. Its dynamic impact energy bursts the old pipe and displaces the fragments into the surrounding soil. A new pipe, of equal or larger diameter, is pulled in simultaneously. The old bore course must be usable for the new pipeline. Lateral inlets or bends have to be opened for a safe, tight, and professional connection. The soil surrounding the old pipe must be displaceable, and the distance to existing pipelines should be > 0.5 m.

The old pipe can be made of clay, cast iron, asbestos cement, plastic, or unreinforced concrete. Pipelines requiring replacement usually have longitudinal cracks, are leaky, are offset, have missing pipe pieces or no pipe bedding, or have partially or completely collapsed. With burstlining it is not always necessary to carry out internal high pressure cleaning or remove any of the old pipeline. Damaged inliners can be replaced by new pipes with the burstlining method by using a special bladed cutting head.

The machine bursts the damaged pipeline and pushes the fragments into the surrounding soil. Simultaneously, the bore profile for the new pipe is expanded. The machine is pulled by a winch, which ensures that line and level are maintained through the existing bore path.

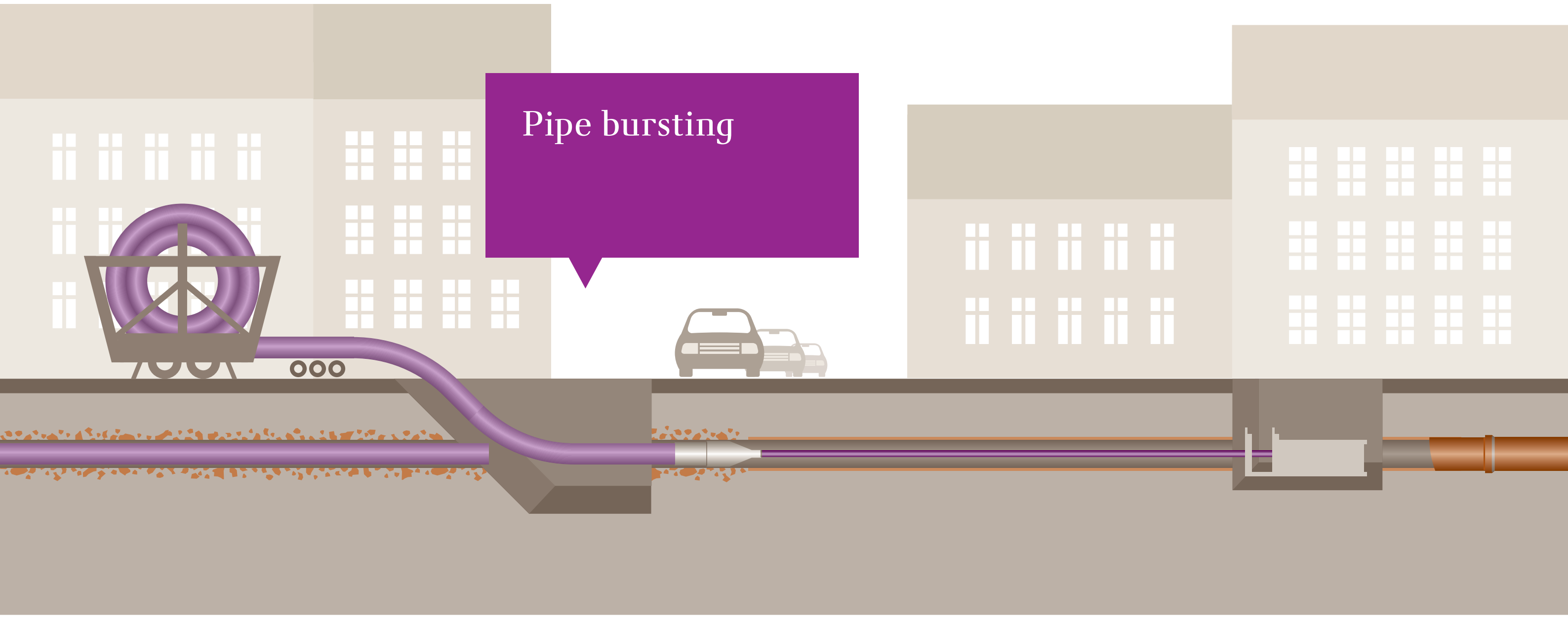
The ground around the old pipe is usually easily penetrated. There are virtually no upsizing limitations. If necessary, the ground plasticity allows the new pipe-carrying capacity to be increased by up to two nominal sizes. Groundwater lowering is only necessary in the starting and exit pits.

The annulus around the new pipe can be filled by using a bentonite/cement-mortar mix during the boring procedure. A mortar collar is formed around the new pipe giving full-surface adhesion and pipe support by the surrounding soil.

PA12 pipes are especially recommended for this procedure. These pipes are highly resistant and sufficiently flexible, and easily adapt to align with the old pipeline. Expanding up to two nominal sizes and strengthening of the pipe wall is possible.

Advantages of the method

- Environmentally friendly, trenchless pipe installations
- Applicable for all types of damaged pipes
- Increase of capacity by one or two nominal pipe sizes is possible.
- Long pipe lengths without joint sockets as well as pressure pipes can also be replaced.
- Improvement of the bedding conditions by filling the pipe annulus
- Innovative and quick; avoids unwanted social costs
- Safe and compliant with technical regulations
- Easy price-saving calculations in advance
- Long life guarantee for new pipes
- Simple – safe – effective



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