



VESTAMID®

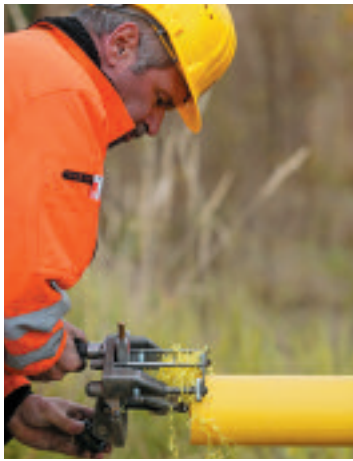
Time Has Come! High-Performance
Polyamides for High-Pressure Gas Pipes



Evonik Industries is the creative industrial group of Germany which operates in the three business areas chemicals, energy and real estate. Evonik is a global leader in specialty chemicals.

Together with the Acrylic Monomers and the Acrylic Polymers Business Lines, the High Performance Polymers Business Line is part of the Performance Polymers Business Unit, and specializes in manufacturing customized products and product systems. We have been producing high-performance materials for over 30 years. The extension towards polyamides for large diameter tubes and pipes represents a logical expansion of our product portfolio.





Content

1 Polyamide 12 (PA 12) pipe extending the benefits of polyethylene	4
2 Enhanced performance characteristics for high-pressure gas distribution applications	5
3 Maximizing the infrastructure assets and contributing to the bottom line	7
4 Proven record of performance	8
5 Frequently asked questions	9
6 VESTAMID® LX9030 (PA 12) for pipes and fittings typical material and physical properties	11





1 Polyamide 12 (PA 12) pipe extending the benefits of polyethylene

VESTAMID® polyamide 12 (PA 12)

Polyamide 12 or Nylon 12 is a high-performance thermoplastic polymer with outstanding chemical, thermal, and mechanical properties. As a result, it is the preferred material of choice in many demanding applications, including fuel lines in passenger cars and air brake tubing in trucks.

Over the past 15 to 20 years, PA 12 pipes have been extensively used in low-pressure and thin wall gas distribution applications in Australia, Poland, and Chile as a safe and cost-effective alternative to metallic piping systems. In addition to being easier to handle and install, the PA 12 pipe eliminates the need for costly long-term corrosion control measures. This positive experience coupled with its excellent performance characteristics have increasingly supported the possibility of using PA 12 piping systems at higher operating pressures between 10 to 20 bar at comparable stress levels as being used elsewhere in the world.

VESTAMID® LX9030 (yellow) is a new high molecular grade PA 12 material developed by Evonik. This material complies with all of the relevant ISO and ASTM standards and specifications for pipe and fittings used for gas distribution applications. In many instances, the performance characteristics of the VESTAMID® PA 12 material exceed current requirements within applicable industry standards. These characteristics make the VESTAMID® PA 12 material an ideal choice when selecting appropriate thermoplastic piping materials in extending your gas distribution infrastructure.

2 Enhanced performance characteristics for high-pressure gas distribution applications

Natural gas distribution companies engage themselves in the installation of world class piping systems which help to serve the ever growing energy needs. As a result, it is of paramount importance to select the best candidate materials with proven performance characteristics which will reduce life cycle costs and perform over their intended design life.

VESTAMID® LX9030 exhibits the following key performance characteristics and benefits for natural gas distribution companies which make it an ideal candidate for high-pressure applications.

Increased long-term strength

Both the ISO (International Organization for Standardization) and ASTM (American Society of Testing and Materials) have established protocols to characterize the long-term performance of thermoplastic pipes used in gas distribution applications. In globally respected ISO standards the long-term hydrostatic strength of a thermoplastic material is represented by the Minimum Required Strength (MRS), which is determined following the methodology and statistical analysis of test data described in ISO 9080 "Plastics Piping and Ducting Systems - Determination of

the Long-Term Hydrostatic Strength of Thermoplastic in Pipe Form by Extrapolation".

In 2002 ISO Sub-Committee 4 (SC 4) established a working group (WG 7) to develop standards for polyamides (PA 12 and PA 11) for gas installations. In 2007 three of five parts are completed covering the requirements for PA materials, PA pipes, and jointing of PA pipes. ISO 22621 "Plastics piping systems for the supply of gaseous fuels for maximum operating pressures up to and including 2 MPa (20 bar) – Polyamide (PA)", Part 1: General, Part 2: Pipes, Part 3: Fittings. VESTAMID® LX9030 (yellow) is in full compliance with ISO 22621 requirements.

Maximum Required Strength according to ISO 9080:

LPL: 18.61 MPa
MRS: 18 MPa

*Based on the 50 years LPL at 20 °C the MRS of VESTAMID® LX9030 is 18 MPa in accordance with ISO 12162:1995E. No knee was detected at 20, 60 or 80 °C.





Excellent slow crack growth resistance

Over 40 years of field experience has demonstrated that the leading cause of failures for plastic piping systems is due to Slow Crack Growth (SCG) resulting in damage or defects to the pipe. There are several factors which can produce SCG failures including poor manufacturing; installation practices such as squeeze-off, excessive bending strain, poor fusion alignment, etc; and environmental factors such as rocky soils.

Both ISO and ASTM standards have incorporated requirements to ensure the piping materials used for gas distribution applications have ample resistance to this known failure mechanism. These include PENT test data (ASTM F 1473) and Notch Pipe Testing (ISO 13479).

According to ISO 22621-2.2, PA 12 pipes (classified MRS 18 MPa) must pass Notch Pipe Testing at 80 °C and 20 bar test pressure (SDR-11), meaning no failure within 500 hours test period. VESTAMID® LX9030 demonstrated excellent SCG resistance. There was no failure after 2000 h even at test conditions significantly higher than those currently required.

Slow Crack Growth (SCG) resistance of PA 12 pipes (SDR-11) in accordance to ISO 13479

- No failures at 20 bar and 80 °C with a 20% notch for over 2000 hours
- No failures at 20 bar and 80 °C with a 30% notch for over 2000 hours
- No failures for 3/6 test specimens at 20 bar and 80 °C with a 50% notch for over 1000 hours

Excellent resistance to rapid crack propagation

Rapid Crack Propagation (RCP) can lead to catastrophic failures in the pipe which can potentially extend at rapid rates over great distances, however, there have been documented only a very few cases of RCP failures worldwide.

With reference to potential RCP incidents ISO 22621-2 limits the maximum operation pressure (MOP) of a PA 12 gas piping system by $P_{critical} \geq 1,5 \text{ MOP}$, where $P_{critical}$ is the maximum pressure at which the crack arrest in a full scale RCP test in accordance to ISO 13478. Through a series of full scale testing and comprehensive small scale testing (S4 testing according to ISO 13477), the test data demonstrates that the VESTAMID® PA 12 material has excellent resistance to RCP for the intended range of higher operating pressures up to 20 bar.

RCP results, full scale test in accordance to ISO 13478

Pipe Size	$P_{critical}$ at 0 °C
110 mm SDR 11 pipe	$P_{c,fs} \geq 30 \text{ bar}$
168 mm SDR 11 pipe	$P_{c,fs} \geq 25 \text{ bar}$

Excellent chemical resistance

A unique benefit of the inherent molecular make-up of the PA 12 is that it has excellent chemical resistance to heavy hydrocarbons making it an ideal candidate material for extremely harsh environmental conditions. As a result, VESTAMID® LX9030 is an ideal candidate material for use in replacement applications where the soils have been contaminated due to gasoline spills, etc.

3 Maximizing the infrastructure assets and contributing to the bottom line

Given its increased performance characteristics, the VESTAMID® LX9030 piping systems offer significant economic benefit as compared to other types of piping systems available in the marketplace.

Maximum operating pressures (MOP)

According to ISO regulations the maximum effective pressure of a gas piping system which is allowed in continuous use is given by

$$\text{MOP (in bar)} = 20 \times \text{MRS} / C \times (\text{SDR}-1)$$

where MRS is the maximum required strength of the pipe material and C the overall service (design) coefficient for the supply of gaseous fuels, which shall be 2 or a higher value according to national regulations.

With MRS = 18 MPa VESTAMID® LX9030 can safely operate up to 18 bar using a design coefficient of 2 covering a big share of gas distribution lines so far only executed in steel. Thus VESTAMID® LX9030 is an alternate to steel installations providing all the technical and cost benefits of a thermoplastic pipe material.

As MRS of VESTAMID® LX9030 is almost 2 times higher than for HDPE thinner wall thicknesses can be designed for installations with medium operation pressures. Given the same outer diameter the flow capacity of a VESTAMID® LX9030 pipe system is then much higher at the same cost for the trench and recovering of the surface.

MRS = 18 MPa at 20 °C	
SDR	C = 2,0
21	9 bar
17	11 bar
13.6	14 bar
11	18 bar



Impact on operations

In addition to its increased performance characteristics and ability to safely operate at higher operating pressures, the VESTAMID® LX9030 material offers seamless and transparent integration within gas utility companies' operations. Evonik in partnership with leading gas component manufacturers is working on a complete line of pipe and fittings to effectively design, construct, and maintain the VESTAMID® LX9030 piping systems. Moreover, existing practices used for PE piping systems such as butt heat fusion joining, electrofusion joining, squeeze-off are readily transferable to VESTAMID® LX9030 piping systems.

Reduced life cycle costs

Like PE, the VESTAMID® LX9030 piping systems offer the same range of economic benefits for gas utility companies as compared to metallic piping.

- The VESTAMID® LX9030 pipe is lightweight and easier to handle and transport
- The VESTAMID® LX9030 piping systems eliminate the need for long term corrosion control measures
- Given its inherent flexibility, the VESTAMID® LX9030 pipes can be provided in coils thereby reducing the number of joints that must be performed in the field resulting in increased productivity and reduced costs
- Together with the pipe coils, the use of planting/plowing installation techniques can be used to install more pipe over a shorter period of time as compared to other methods of installation
- Depending on the application and capacity considerations, the VESTAMID® LX9030 piping systems can be utilized with thinner wall applications and thereby further reducing material costs and maximizing capacity
- The VESTAMID® LX9030 pipes can be utilized with an array of low-cost trenchless rehabilitation techniques including horizontal directional drilling, sliplining, pipe bursting, etc.

4 Proven record of performance

In order to demonstrate the safe performance of VESTAMID® LX9030 piping systems at higher operating pressures and over a range of environmental/climatic conditions, several installations have been successfully completed with the support of leading gas utility companies throughout the world and the Gas Technology Institute (GTI). In all of the installations the VESTAMID® LX9030 piping systems have been performing safely with no leaks being reported from the pipe or from the various types of joints (heat fusion, electrofusion, mechanical, and steel/PA12 transition fittings).

Installation permit of test installations in Germany from TÜV Nord and SKZ

In May 2008 TÜV Nord Systems GmbH & Co KG and SKZ TeConA GmbH issued a special permit*) for high pressure gas installations with VESTAMID® LX9030. Based on the presented comprehensive test data the expert report states the safe operating of pipe systems with VESTAMID® PA 12 material for operating pressures up to 18 bar.

*) single permit (Einzelzulassung) in accordance with GasHLVO

High pressure VESTAMID® LX9030 test installations in Germany

Site	Description
Eon Ruhrgas Technical Center Dorsten, Germany, since Nov. 2005	60 m D110 SDR-11 test pipe from a coil with butt fusions and electro-fusion couplings and end caps, operating at 25 bar in a D500 steel host-pipe. No distinctive features
	A shorter track of 3 m, also with a butt fusion, an electro-fusion coupling and end caps, was operated at 36 bar for 2 years, without any distinctive features

High pressure VESTAMID® LX9030 test installations in USA

Site	Description
GTI installation, Des Moines, IL, USA	2 inch (D60) SDR 11 with butt fusion joints and electro-fusion couplings operating at 17.3 bar air, installed Feb. 2005 2 lines 6 inch (D170) SDR 11 with butt fusion joints and electro-fusion couplings, operating at 17.3 bar air, installed Nov. 2006, one buried with "80/20 rocky soil mixture", one under "flowable fill" (heavy load)
National Fuel, Buffalo, NY, USA	6 inch (D170) SDR 11 with butt fusion joints and electro-fusion couplings, operating at 17.3 bar natural gas, with a critical bending radius, installed Nov. 2006, wet cold environment
City of Mesa, Mesa, AZ, USA	4 inch (D114) SDR 11 with butt fusion joints and electro-fusion couplings, designed for 60 °C maximum ambient temperature, operating at 9.6 bar nitrogen in low depth under heavy truck passage, installed March 2008
MichCon/DTE, Detroit, MI, USA	4 inch (D114) SDR 11 with butt fusion and electro-fusion joints, 22.8 bar nitrogen, installed May 2008
WE-Energy, WI, USA	4 inch (D114) SDR 11 with butt fusion joints, operating at 17.3 bar air, installed May 2008
Atmos Energy, Meridian, MS, USA	6 inch (D170) SDR 13.5, in-service installation operating at 12 bar, planned for winter 2008/2009

5 Frequently asked questions

What are the moisture absorption characteristics of the PA 12 materials?

Like all polyamide materials, PA 12 is also hygroscopic. However, in comparison to other polyamide materials, the PA 12 material absorbs the lowest amount of moisture. The equilibrium moisture content is 1.5% for PA 12 (for comparison PA 6 is 8.5% and PA 11 is 1.8%).

In addition, based on comprehensive testing data to characterize the integrity of heat fusion joints made in accordance to qualified VESTAMID® LX9030 joining procedures, the moisture absorption characteristics of the PA 12 pipe does not adversely impact the overall joint strength.



**Our technical expert:
Andreas Dowe**

Frequently asked questions

Is a complete VESTAMID® PA 12 piping system available?

Due to the excellent processability of VESTAMID® LX9030 pipes are easily processable on existing PE pipe extrusion equipment. A complete line of fittings is in development at leading component manufacturers to complete PA 12 piping systems including transition fittings, electrofusion fittings, and mechanical saddle fittings.

Are there special considerations when joining the VESTAMID® PA 12 pipes?

No. Qualified VESTAMID® LX9030 butt heat fusion procedures have been developed and qualified through comprehensive testing. The German DVS will publish the guideline DVS 2207-16 (butt fusion of PA 12) beginning 2009. The qualified procedures are analogous to established joining procedures for PE materials with the exception of using a 240 °C heater iron temperature. This temperature is slightly higher than current guidelines for PE.

Are there special repair fittings available for PA 12 piping systems?

A significant benefit of the VESTAMID® LX9030 piping system is that existing construction and maintenance practices specific to PE are readily transferable to PA 12 piping systems. As a result, gas utility companies can employ the same safe and effective practices which they routinely utilize to address emergency response and repair considerations for their VESTAMID® LX9030 piping systems as they currently do with the PE piping systems.

Does the yellow pigment adversely impact the overall performance of the VESTAMID® PA 12 pipes?

No. Evonik has comprehensive protocols in place to ensure that VESTAMID® LX9030 (yellow) as a well balanced compound of resin, stabilizers, and pigment can effectively ensure safe long-term performance for the intended application and

that there are no adverse reactions.

Ageing tests on samples from field installations testify already long-term laboratory tests.

According to ISO 22622 also PA 11 is suitable for high pressure gas piping systems. Is there a significant difference compared with PA 12?

PA 11 and PA 12 are very similar from their molecular structure, differences are slightly but significant with respect to gas piping designs. PA 11 has a lower mechanical strength with MRS = 16 MPa (HDB 2500 psi), thus the maximum allowable operation pressures are lower, or required wall thicknesses are higher respectively.

Are PA 12 and PA 11 cross fuseable?

PA 12 and PA 11 are not compatible. Therefore a cross fusion is not recommended. At certain conditions a chemical reaction which results in a re-amidation might be possible. Because these conditions have an extremely narrow window and need temperatures above 260 °C they are not applicable under field conditions.





6 VESTAMID® LX9030 (PA 12) for pipes and fittings

Typical material and physical properties

Material designation			VESTAMID® PA 12	
Pipe properties	Unit	Test method	Typical value	
Minimum Required Strength (MRS)	MPa	ISO 9080	18	
Notch Pipe Test 20 bar, 80°C	h	ISO 13479	> 2000	
Point Loading Test 20 bar, 80°C	h		> 2000	
Rapid crack propagation, D110 SDR 11 critical pressure (PC), 0 °C	bar	ISO 13478	30	
Rapid crack propagation, D168 SDR 11 critical pressure (PC), 0 °C	bar	ISO 13478	25	
Pipe test category	-	ISO 22621-2		
Material properties				
Density	g/cm ³	ISO 1183	1.02	
Tensile strength at yield	MPa	ISO 527	40	
Strain at break	%	ISO 527	> 200	
Flexural Modulus	MPa	ISO 527	1300	
PENT (2.4 MPa)	hrs	ASTM F1473	> 2000	
PENT (4.8 MPa)*	hrs	-	> 2000	
Moisture absorption 23 °C/50 % r.h.	%	ISO 62	0.8	
Water absorption saturation	%	ISO 62	1.5	
Thermal properties				
Melting range DSC 2nd heating	°C	ISO 11357	177	
Vicat softening temperature	°C	ISO 306		
Method A 10 N			170	
Method B 50 N			150	

*Test specimen and overall test methodology are the same as ASTM F1473 but at increased stress levels

Your contacts

Technical support

Andreas Dowe
PHONE +49 2365 49-7369
MOBILE +49 151 15101718
andreas.dowe@evonik.com

Northern Germany, Benelux

Karsten Goldstein
PHONE +49 2365204790
MOBILE +49 1718130033
karsten.goldstein@evonik.com

Southern Germany, Iberia

Ludger Malmedy
PHONE +49 8251870157
MOBILE +49 1718130072
ludger.malmedy@evonik.com

Central Germany

Achim Hiltrop
PHONE +49 2017988871
MOBILE +49 1718130045
achim.hiltrop@evonik.com

Austria, Switzerland

Beat Bertschinger
PHONE +41 19380665
MOBILE +41 794453703
beat.bertschinger@evonik.com

Czech. Republic, Slovakia

Miroslav Sarman
PHONE +420 272111817
MOBILE +420 602336106
miroslav.sarman@evonik.com

France

Géraud Apchin
PHONE +33 139757985
MOBILE +33 607244714
geraud.apchin@evonik.com

Italy

Roberto Sacchi
PHONE +39 0371219363
MOBILE +39 3356840731
roberto.sacchi@evonik.com

Nordic

Göran Winnerstam
PHONE +46 40459500
MOBILE +46 706094570
goeran.winnerstam@evonik.com

Poland

Andrzej Wolak
PHONE +48 223181007
MOBILE +48 603202152
andrzej.wolak@evonik.com

Turkey

Mehmet Ali Ersudas
PHONE +90 2163959961255
MOBILE +90 5322311525
ali.ersudas@evonik.com

UK, Eire

Hameem Yasin
PHONE +44 1214432016
MOBILE +44 7890536447
hameem.yasin@evonik.com

Australia

Peter Gibson
PHONE +61 298914011
MOBILE +61 418270474
peter.gibson@evonik.com

China

Kenny Chee
PHONE +86 2161191359
MOBILE +86 13816673822
kenny.chee@evonik.com

India

Ashok Bandella
PHONE +91 2256307070
MOBILE +91 9820211866
ashok.bandella@evonik.com

Korea

Hongil Kim
PHONE +82 325102442
MOBILE +82 112520181
hongil.kim@evonik.com



EVONIK
INDUSTRIES

Evonik Degussa GmbH

High Performance Polymers
45764 Marl
Germany

PHONE +49 2365 49-9878
FAX +49 2365 49-5992
www.evonik.com/hp

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