EVONIK INDUSTRIES

VESTAMID® Polyamide 12
Innovative and reliable

VESTAMID®

Evonik. Power to create.

Evonik, the creative industrial group from Germany, is one of the world's leading specialty chemicals companies. Its activities focus on the key megatrends health, nutrition, resource efficiency and globalization. Evonik is active in over 100 countries around the world.

The High Performance Polymers Business Line produces customized products, systems, and semi-finished products based on high performance polymers that are used in areas such as automobiles, sport applications, oil production, and photovoltaics. Evonik produces a range of VESTAMID® polyamide 12 products with customized properties that we have been continuously adapting to meet the demands of innovative, high-quality applications in close collaboration with our customers for more than 50 years.

Evonik. Power to Create.

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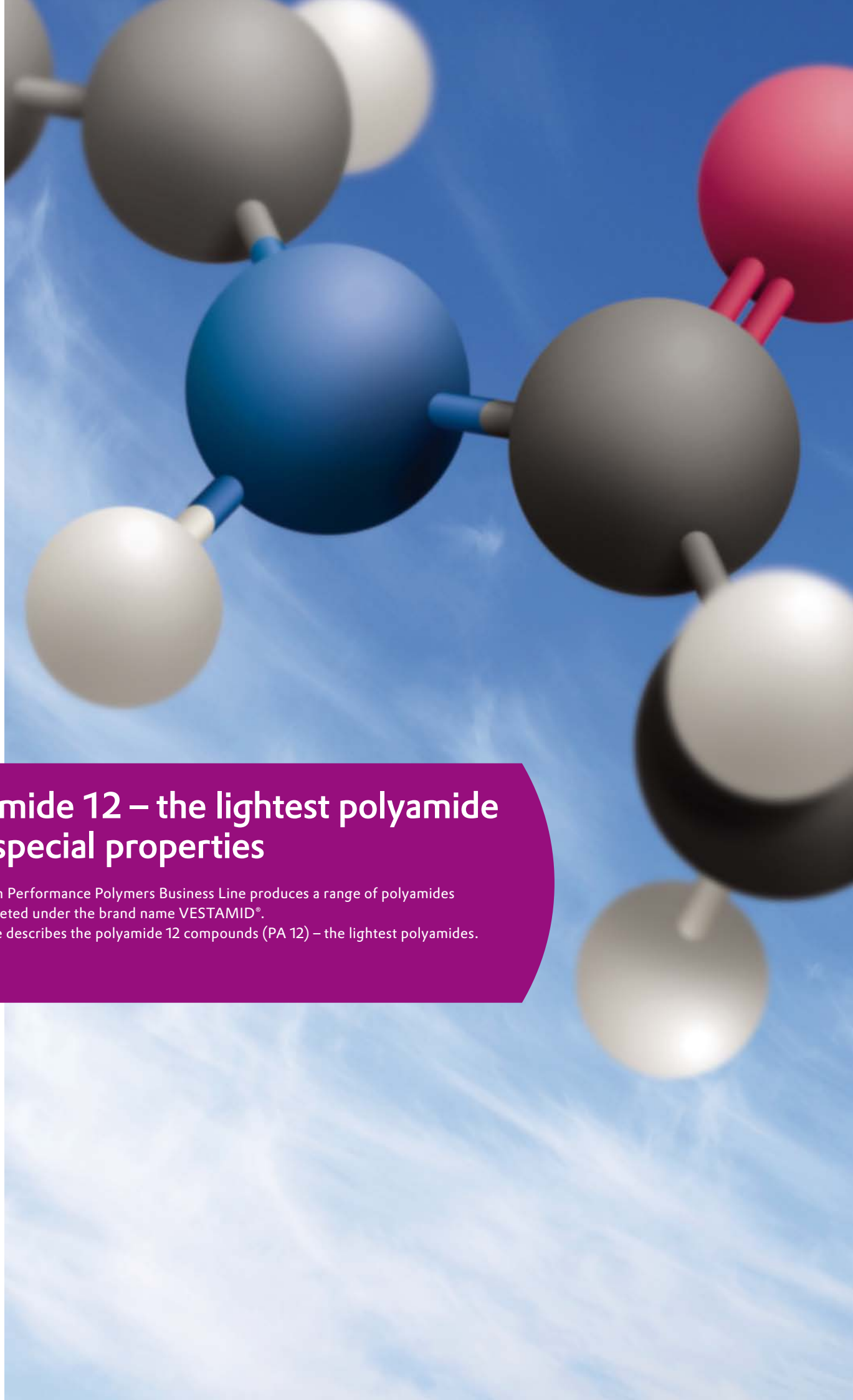


Polyamide 12 – the lightest polyamide with special properties

Evonik's High Performance Polymers Business Line produces a range of polyamides that are marketed under the brand name VESTAMID®.
This brochure describes the polyamide 12 compounds (PA 12) – the lightest polyamides.

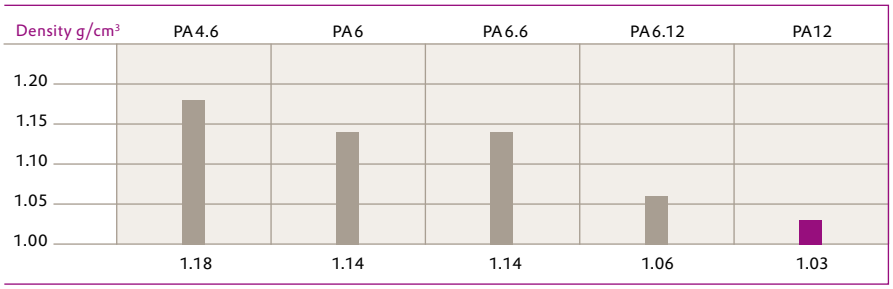
VESTAMID® L
Polyamide 12

In general, it can be said that long-chain, semi-crystalline polyamides absorb little water, are resistant to polar and non-polar solvents, exhibit low creep behavior and high impact resistance and can be used in a wide temperature range. Virtually no other polymer material in this price range exhibits these properties.

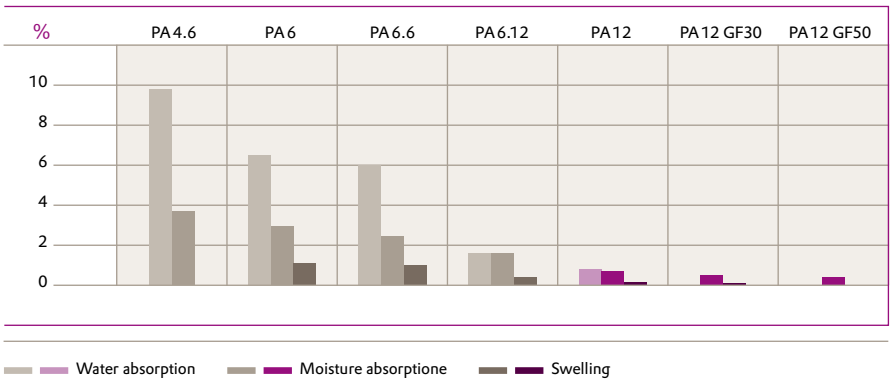
The (carbon)amide groups (-CO-NH-) in polyamides are responsible for the formation of hydrogen bonds between the macromolecular chains. The hydrogen bonds contribute to the crystallinity, increase the strength, the melting point and the chemical resistance. These properties are characteristic for all semi-crystalline polyamides. PA 12 has the lowest concentration of amide groups of all commercially available polyamides. This is also responsible for the special properties of PA 12:

- Lowest water absorption of all commercially available polyamides. As a result, the properties vary little and molded parts exhibit almost no dimensional changes with variations in humidity.
- Extraordinarily high impact resistance and notched impact strength – immediately after injection molding and also well below the freezing point
- Good to very good resistance to greases, oils, fuels, hydraulic fluids, and many solvents as well as to salt solutions, etc.
- Excellent resistance to stress cracking, even for metal parts encapsulated by injection molding or embedded
- Excellent abrasion resistance
- Low coefficient of sliding friction, in dry running against steel, polybutylene terephthalate, polyacetal and other materials
- Noise and vibration damping properties
- Excellent resistance to fatigue caused by frequent load change
- High processability

Density of various polyamides

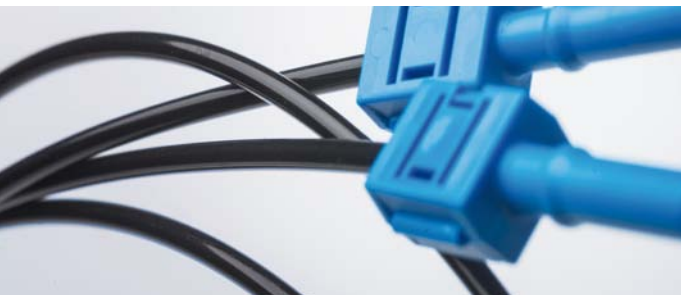


Water and moisture absorption and swelling of different polyamides



1.1 Product overview

The most important polyamide 12 compounds and their typical applications



The VESTAMID® range includes various products that have been customized to suit the requirements of different applications. These are listed in the tables below.
The tables of properties at the end of the brochure contain more detailed information about most of the compounds. Information about the other compounds is available on request.

In addition to the VESTAMID® L polyamide 12 compounds described here, Evonik produces other polyamide 12 compounds for medical applications that are marketed under the VESTAMID® Care brand, and compounds for oil and gas pipes, which are called VESTAMID® NRG. These products are described in separate brochures.

More properties of VESTAMID® compounds and material information about the other products from the High Performance Polymers Business Line can be found in the Campus® plastics information system. You can find this on the Internet

→ www.vestamid.com
→ Products & Services

Campus® is a registered trademark of CWF GmbH/Frankfurt (Main).

Unfilled VESTAMID® polyamide 12 compounds

VESTAMID®	Description acc. to ISO 1874-1	Characterization	Processing	Tensile modulus [MPa]	Applications
L1600	PA12, XN, 12-010	low viscosity base polymer	I, E, C	1300	additive concentrates for colorants and stabilization, processing aid
L1700	PA12, XN, 14-010	low viscosity base polymer	I, E, C	1300	as L1600
L1901	PA12, XN, 18-010	medium viscosity base polymer	I, E, C	1300	as L1600
L1670	PA12, KHL, 12-010	low viscosity, heat and light stabilized, with processing aid	I, E	1400	wire insulation, coils, secondary coating of optical fibers
X7377 black	PA12, HHL, 12-020	low viscosity, heat and light stabilized, with adhesion promoter	E	1650	extrusion coating of metal tubing
L1940	PA12, KH, 18-010	medium viscosity, heat stabilized with processing aid	I, E	1400	loose tubing for optical fibers, sheathing for steel cables
L1970	PA12,KHL, 18-020	medium viscosity, heat and light stabilized	E	1600	cable sheathing, tubing, rods, profiles
LX9009	PA12, FL, 16-010	medium viscosity, light stabilized	E	1300	ski cover films
X7373	PA12, MHR, 18-010N	medium viscosity, heat stabilized, nucleated for very short cycle times	I	1500	filter and valve housings, bushings, connectors
L1950 black	PA12, MHS, 18-020	medium viscosity, heat stabilized, reduced friction and wear through molybdenum disulfide modification	E	1550	guide rails, friction bearings
L2101F	PA12, F, 22-010	high viscosity, steam sterilizable	E	1400	packaging films
L2106F	not applicable	high viscosity, very high transparency, modified by comonomers	E	1300	flexible tubular films for sausage casings
L2140*	PA12, EHL, 22-010	high viscosity, heat and light stabilized, with processing aid	E	1400	fuel lines, sheaths for steel cables, semi-finished products, tubing for car window lifters
L2170	PA12, EHL, 22-010	high viscosity, heat and highly light stabilized, with processing aid	E	1400	UV-stable and termite-resistant cable sheathing
L2141 black	PA12, EHL, 22-010	high viscosity, light and higher heat stabilized than L2140, with processing aid	E	1500	hydraulic clutch lines, vacuum lines
LX9001 black	PA12, HHL, 22-020	high viscosity, heat and light stabilized, with adhesion promoter	E	1650	extrusion coating of metal tubing
LX9008	PA12, HI, EHL, 22-010	high viscosity, highly heat stabilized	E	1450	hot diesel fuel lines
LX9016	PA12, EHL, 22-010	high viscosity, heat and light stabilized	E, I	1070	sport shoe soles, ski cover films

E = Extrusion, I = Injection molding, C = Compounding

*VESTAMID® L2140B for use in food contact applications on request

1.2 Product overview

Plasticized VESTAMID® polyamide 12 compounds

VESTAMID®	Description acc. to ISO 1874-1	Characterization	Processing	Tensile modulus [MPa]	Applications
L1723	PA12-P, MHL, 14-005	low viscosity, plasticized, heat stabilized, with mold release agent	I	480	cable ties, fastening elements
L2121	PA12-P, EHL, 22-007	high viscosity, plasticized, light and heat stabilized, with processing aid	E	700	fuel, vacuum, and hydraulic lines, steel cable sheathing
L2122	PA12-P, EHL, 22-005	high viscosity, plasticized, light and heat stabilized, with processing aid	E	490	fuel, vacuum, and hydraulic lines, steel cable sheathing
X7393	PA12-HIP, EHL, 22-005	high viscosity, plasticized, light and heat stabilized	E	580	air brake line systems, for higher operating pressures
X7297 black	PA12-HIP, EHL, 22-004	high viscosity, plasticized, light and heat stabilized	E	400	flexible tubing and hoses
L2124	PA12-P, EHL, 22-004	high viscosity, plasticized, light and heat stabilized, with processing aid	E	400	fuel, vacuum, and hydraulic lines, steel cable sheathing
L2123	PA12-P, EHL, 22-004	high viscosity, plasticized, light and heat stabilized, with processing aid, increased cold impact strength	E	370	air brake line systems
X7293	PA12-HIP, EHL, 22-004	high viscosity, plasticized, light and heat stabilized, with processing aid, increased cold impact strength	E	400	air brake line systems
L2128	PA12-P, EHL, 22-002	high viscosity, plasticized, light and heat stabilized, with processing aid	I, E	230	very flexible tubing and hoses for pneumatic systems
LX9013	PA12-HIP, EHL, 22-004	high viscosity, plasticized, highly heat stabilized	E	410	hot diesel fuel lines

E = Extrusion, I = Injection molding

Reinforced, filled and flame-retardant VESTAMID® polyamide 12 compounds

VESTAMID®	Description acc. to ISO 1874-1	Characterization	Processing	Tensile modulus [MPa]	Applications
L-GF15	PA12, MHR, 16-040, GF15	15% chopped strands, medium viscosity, heat stabilized with processing aid	I	3900	gear box housing for electrical car window lifters
L1833	PA12, MHR, 16-050, GF23	23% chopped strands, medium viscosity, heat stabilized with processing aid	I	5300	connectors for fuel lines
L-GF30	PA12, MHR, 18-070, GF30	30% chopped strands, medium viscosity, heat stabilized with processing aid	I	6500	bearing cups for windshield wipers
L1930	PA12, MHR, 18-040, GD30	30% milled glass fibers, medium viscosity, heat stabilized with processing aid	I	4000	gear wheels, castors, pump parts, sliding bearings, connectors
L-GB30	PA12, MHR, 16-020, GB30	30% microglass beads, medium viscosity, heat stabilized with processing aid	I	2000	precision-molded parts with isotropic shrinkage, e.g., housings for gears, control valves and mechanical counters, pump impellers
X7000	PA12-HI, MFH, 12-010	low viscosity, with flame retardant, light and heat stabilized, impact-modified	I	1400	molded parts with good light and heat stability
X7166	PA12, KFH, 12-020	low viscosity, with flame retardant, halogen and phosphorus-free, UL94-V0/V2, with processing aid	I, E	1800	wire insulation
X7167	PA12, EFH, 22-020	high viscosity, with flame retardant, halogen and phosphorus-free, UL94-V2, with processing aid	E	1700	profiles for aircraft interiors
X7229	PA12-P, EFH, 22-010	high viscosity, plasticized, with flame retardant, halogen and phosphorus-free, UL94-V2, fulfills FAR 25.853b	E	1000	profiles and tubing
LX9104	PA12-HIP, EFH, 22-010	high viscosity, plasticized, with flame retardant, halogen free, UL94-V0, increased cold impact strength	E	800	profiles and (corrugated) tubing

E = Extrusion, I = Injection molding

1.3 Product overview

Permanently antistatic and electrically conductive VESTAMID® polyamide 12 compounds

VESTAMID®	Description acc. to ISO 1874-1	Characterization	Processing	Tensile modulus [MPa]	Insulation resistance [Ohm]*	Applications
L-R3-MHI black	PA12-HI, MHZ, 16-020	medium viscosity, heat and light-stabilized, increased cold impact strength, with processing aid	I	1600	10^4	antistatic and electrically conductive injection molded or extruded parts for use in areas prone to explosion such as coal mining and other industries, e.g., housings for explosion-protected measurement, fans for electric motors, housings for electric switches, chair castors, loudspeaker boxes, telephone and radio equipment, profiles for assembly lines, also with electric shock protection
L-R4-MHI black	PA12-HI, MHZ, 16-010	medium viscosity, heat and light-stabilized, increased cold impact strength, with processing aid	I	1250	10^5	
L-R7-MHI black	PA12-HI, MHZ, 16-010	medium viscosity, heat and light-stabilized, increased cold impact strength, with processing aid; especially designed for parts meeting EN 50014	I	1400	10^6-10^9	
L-R9-MHI black	PA12-HIP, MHZ, 16-010	medium viscosity, heat and light-stabilized, increased cold impact strength, with processing aid; especially designed for parts meeting EN 50014	I	1400	10^8-10^{11}	
L-R3-EI black	PA12-HI, EHZ, 22-010	high viscosity, heat and light-stabilized, increased cold impact strength, with processing aid	E	1500	10^3	
L-R2-GF25 black	PA12, MHZ, 18-060, GF25	medium viscosity, 25% chopped strands, heat and light stabilized	I	6500	10^2	
X7380 black	PA12-HI, MHZ, 16-050, GF23	medium viscosity, 23% chopped strands, heat and light stabilized, increased cold impact strength	I	5400	10^7	quick connectors in conductive fuel line systems
LX9112 black	PA12, EHLZ, 18-020	medium viscosity, conductive, heat and light stabilized, with adhesion promoter	E	2000	10^6	extrusion coating of metal tubing
LX9102 black	PA12-HIP, EHLZ, 22-005	high viscosity, conductive, plasticized, with processing aid, increased cold impact strength	E	640	10^4	electrically conductive tubing

E = Extrusion, I = Injection molding

* determined on specimens acc. to DIN EN 50014; corresponds to ROE in DIN 53482:1983

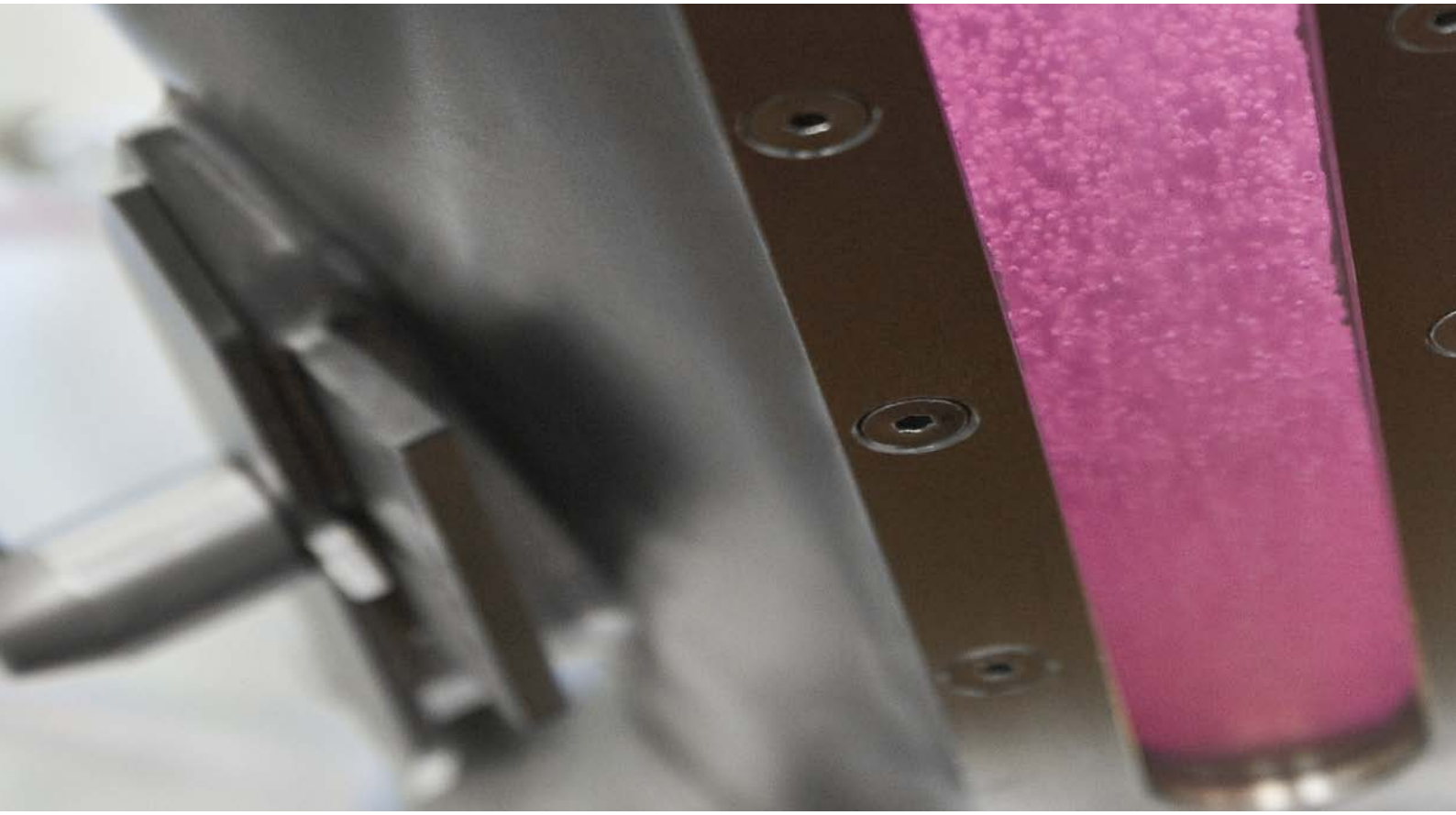
VESTAMID® polyamide 12 compounds for extrusion of multi-layer tubing systems for automotive fuel lines

VESTAMID®	Description acc. to ISO 1874-1	Characterization	Tensile modulus [MPa]	Use in multi-layer tubing systems
X7293	PA12-HIP, EHL, 22-004	high viscosity, plasticized, light and heat stabilized, with processing aid, increased cold impact strength	400	140
LX9002	PA12-HIP, EHL, 22-004		400	2030, 2040, 4300, 4500, 4540, 7440
LX9010 black	PA12-HIP, EHL, 22-004		400	1000
X7297 black	PA12-HIP, EHL, 22-004	high viscosity, plasticized, heat and light stabilized	400	7000, 7040
X7395 black	PA12-HIP, EHLZ, 16-005	medium viscosity, plasticized, electrically conductive, light and heat stabilized, with processing aid, increased cold impact strength	580	2040.1 inner layer
LX9102 black	PA12-HIP, EHLZ, 16-007		600	140.2, 2040.2 inner layer
LX9110 black	PA12-HIP, EHLZ, 22-007	high viscosity, plasticized, electrically conductive, light and heat stabilized, with processing aid, increased cold impact strength	640	4540 inner layer
LX9109 black	PA12-HIP, EHLZ, 22-007	high viscosity, plasticized, electrically conductive, highly heat stabilized	650	140.3 (diesel) inner layer

VESTAMID® polyamide 12 compounds for the production of quick connectors for automotive lines

VESTAMID®	Description acc. to ISO 1874-1	Characterization	Tensile modulus [MPa]	Applications
X7373	PA12, MHR, 18-010N	medium viscosity, heat stabilized, nucleated for very short cycle times	1500	quick connectors
L1833	PA12, MHR, 16-050, GF23	medium viscosity, 23% chopped strands, heat stabilized with processing aid	5000	quick connectors for single and multi-layer fuel lines
L-GF30	PA12, MHR, 18-070, GF30	medium viscosity, 30% chopped strands, heat stabilized with processing aid	6500	quick connectors for single and multi-layer fuel lines
X7380 black	PA12-HI, MHZ, 16-050, GF23	medium viscosity, 23% chopped strands, heat and light stabilized, increased impact strength	5400	quick connectors for electrically conductive fuel lines, especially for multi-layer tube systems 140, 2040, 4540, 7040, 7440

2 Handling



Delivery and storage

VESTAMID® compounds are delivered as granules in 25 kg moisture-proof containers; for larger orders we can also provide 1,000 kg Octabins. Based on our experience, the product can be stored for an almost unlimited time, assuming the packaging is not damaged.
A storage temperature of 45°C should not be exceeded – especially for plasticized compounds; VESTAMID® LX9008 and VESTAMID® LX9013 may not be subjected to temperatures above 30°C. In our general technical terms and conditions of delivery, we guarantee a storage period of two years, assuming the packaging is not damaged and the material is stored at maximum 30°C.

Drying

When the container has been opened, the compounds can be processed immediately and no pre-drying is necessary.
The granules have to be dried only if the packaging has been damaged or if the container has been open for more than two hours. In these cases, dry the compounds until the water content is below 0.1%.
If there is too much moisture in the compound, this can cause problems in the processing and/or deterioration in the properties of the molded parts. If they are dried for a long time, the compounds may discolor. With compounds containing plasticizer, some plasticizer may be lost through drying.

Incompatibility with other thermoplastics

VESTAMID® is not compatible with most other plastics, including other polyamides. The properties of molded parts made from VESTAMID® that contain traces of another plastic are generally not as good as those made from VESTAMID® with no contamination. Therefore, the processing machine must be cleaned thoroughly before the start of production.

Coloring

Like other semi-crystalline polyamides, unmodified VESTAMID® appears transparent in the melt and opaque white when it is solid (natural color). If not restricted by special additives, VESTAMID® can be colored in any color you wish. Most compounds are delivered in their natural color or black. Because of their additives, others, such as the permanently antistatic compounds, have a special color. Specially colored compounds can be delivered if the order is large enough. No lead or cadmium-based colorants are used.

VESTAMID® compounds can also be colored during processing. The preferred method is to use PA 12-based color concentrates. Dry coloring by tumbling with finely powdered colorants is another possibility but is nonetheless inconvenient. Pneumatic conveyance is then ruled out. Using “neutral” based color pastes or color concentrates can lead to incompatibilities with PA 12. In addition to inconsistent color distribution, this may also result in the mechanical failure of molded parts. Therefore, it is very important that you check the compatibility of a color concentrate with the compound.
The indicated contact persons will be happy to provide more information and support.

3 Physiological and toxicological evaluation

Flame retardant grades

VESTAMID® compounds containing flame retardants do not contain any polybrominated diphenyls or diphenyl ether. Compounds with flame retardants containing no halogens or phosphorus are also available.

No pigments or fillers containing cadmium are used.

Damage to the material during processing can be seen by discoloration in the melt. Damaged material should be removed from the machine as quickly as possible and be cooled under running water to prevent smells.

Environmental compatibility and safety

VESTAMID® compounds are non-hazardous and not harmful to water. They are not subject to particular safety regulations (except VESTAMID® L2128nf, WGK2). With consideration of local regulations, they can be disposed of like household waste in landfill sites or in incineration facilities. The corresponding EC safety data sheets for the products contain more information. For economic and ecological reasons, recycling is preferable to disposal.

If processed correctly, VESTAMID® compounds produce no dangerous by-products. However, as with every thermoplastic process, it is important to ensure adequate ventilation and air extraction – especially with compounds containing plasticizers or flame retardants.

Flammability

Most VESTAMID® compounds are flammable. At mass temperatures above 350°C flammable gases form through decomposition. With sufficient air, incineration produces CO, CO_2, H_2O, and compounds containing nitrogen as the end products. Since the spectrum of cracking and incineration products depends largely on the burning conditions, it is not possible to generalize. You will find all the necessary information in the corresponding safety data sheets that you receive with your delivery or on request.

Food contact

EU status

Following the harmonization of European laws and ordinances, new regulations also apply to plastics that come into contact with food. Commission Regulation (EU) 10/2011 came into effect on May 1, 2011.

The VESTAMID® L base products in the PA 12 series are approved for food contact in the European Union, as the base monomer laurolactam and the additives are on the positive list in Regulation (EU) 10/2011.
For laurolactam, the migration limit is five milligrams per kilogram food, which must be tested and complied with on the finished article itself.

It must be remembered that the unstabilized compounds can be sterilized in hot air at up to 120°C for no longer than 30 minutes. If stabilization or the use of certain additives is required, we will be happy to provide the necessary information on a case-by-case basis.

FDA approvals

According to 21 CFR §177.1500 (Nylon Resins) of the Food and Drug Administration (FDA), PA 12 is approved in the USA for films to a thickness of 40 micrometers.
The base products VESTAMID® L1600, L1700, L1800, L1901, and L2101F are included in this approval.

Medical technology

Evonik markets polyamide 12 compounds that are suitable for medical applications under the brand name VESTAMID® Care. These are described in a separate brochure.

4.1 Product properties

Long-term properties of PA 12 under mechanical stress

At higher temperatures the products can exhibit flow or creep, especially in the case of non-reinforced thermoplastics under stress. With PA 12, creep is relatively low; however, designers must take into account the reduced long-term creep modulus under permanent stress compared to the short-term tensile modulus. On the other hand, this also means that the initial stress is reduced at constant elongation.

Usually, the creep behavior is determined in a monaxial tensile creep test according to ISO 899 at different loads and temperatures. The figures show creep curves and creep modulus curves at room temperature, 60, and 100°C as examples for a VESTAMID® L compound.
The stress-strain curves, time-stress curves, and tensile creep modulus curves can be calculated from time curves that have been linearized by regression analysis.

Fibers used for reinforcement (glass or carbon fibers) reduce creep in the orientation direction of the fibers, while adding plasticizers increases the tendancy to creep.
Thermoplastics containing plasticizers lose plasticizer at high temperatures. This causes contraction, which overlays the expansion caused by external stress. With a linear course of the creep curves, for average expansions with the corresponding stress, the curve can usually be extrapolated up to ten times the duration of the test, assuming there are no damaging environmental influences, such as weathering, lighting, hot air, hot water, or chemicals. Measurements up to 10,000 hours are available for many VESTAMID® L compounds.

Contact us if you require any details.

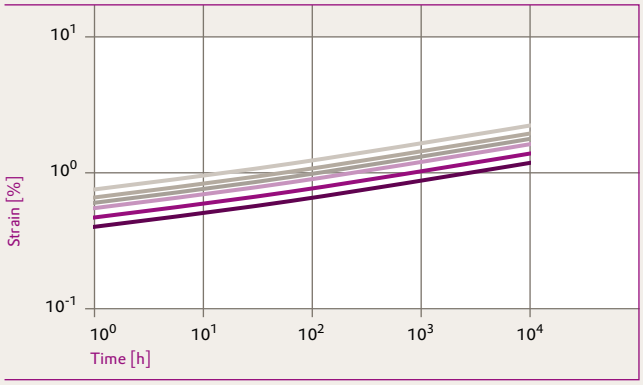
VESTAMID® L1930
Tensile creep test
acc. to ISO 899-1

- 8.5 MPa
- 10.0 MPa
- 11.5 MPa
- 12.5 MPa
- 13.5 MPa
- 15.0 MPa

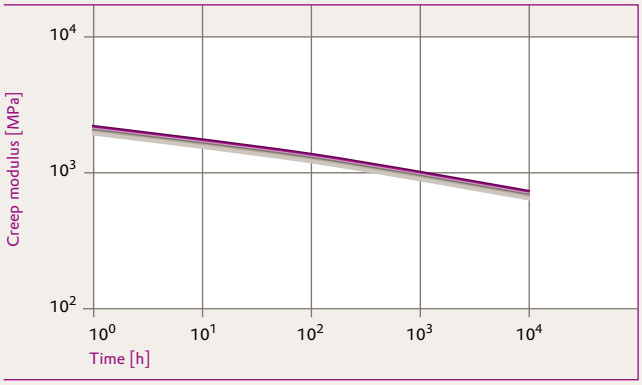
- 8.5 MPa
- 10.0 MPa
- 11.5 MPa
- 12.5 MPa
- 13.5 MPa
- 15.0 MPa

- 6.5 MPa
- 7.5 MPa
- 8.5 MPa
- 9.5 MPa
- 10.5 MPa

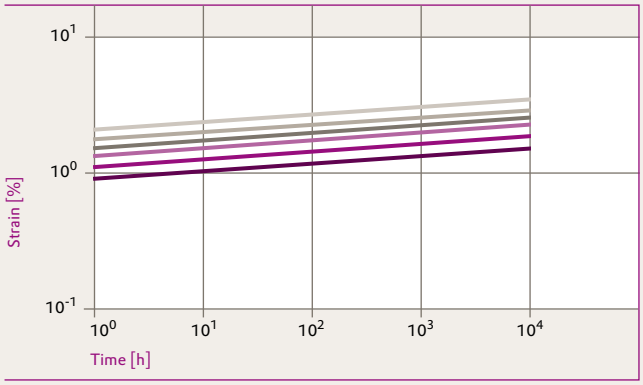
Tensile creep curves of 23°C / 50% r.F.



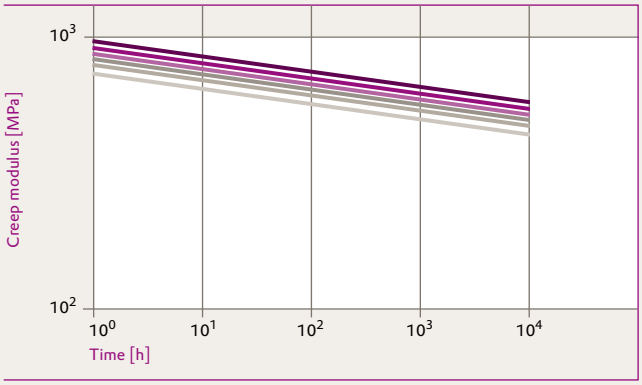
Tensile creep modulus curves of 23°C / 50% r.F.



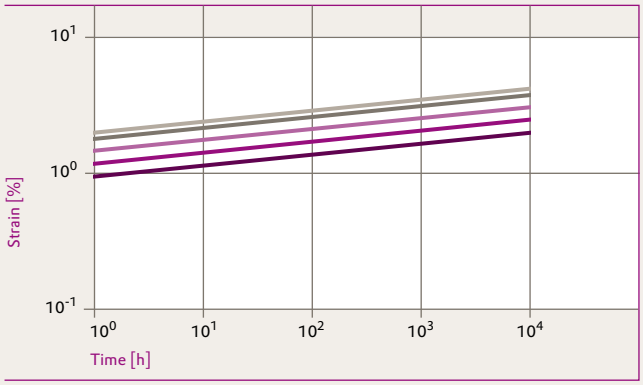
Tensile creep curves of 60°C



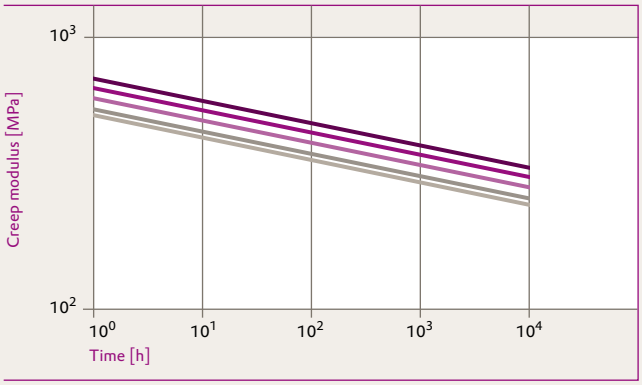
Tensile creep modulus curves of 60°C



Tensile creep curves of 100°C



Tensile creep modulus curves of 100°C



4.2 Product properties

Heat aging

Heat stabilizers considerably improve the aging behavior of plastics, allowing them to be subjected to higher temperatures for longer periods. Apart from a few special products, all VESTAMID® L compounds have an optimized stabilizer system. Heat aging according to IEC 216 is carried out at several temperatures to check the long-term temperature stress that a plastic is able to withstand. In this test, the time that it takes for the mechanical property that is important for the application to decline to 50% of its original value is determined. The values are often extrapolated to 20,000 hours (or a different time frame) and produce the temperature index TI.

For several VESTAMID® L compounds there are also classifications according to UL 746B for the relative temperature index TI. In this case, TI indicates the long-term performance for approx. 60,000 hours.
The product information "Underwriters Laboratories (UL) test certificate for thermoplastic compounds from Evonik Industries AG" contains details.

More information about heat aging is available on request.

Hydrolysis resistance

Polycondensation products, to which polyamides also belong, have a limited resistance to hot water or moist air at higher temperatures. PA 12 has good hydrolysis resistance compared to other polyamides, but it is gradually molecularly degraded by hot water. Compounds with a high molecular mass will last longer than those with a low molecular mass. Hydrolytic degradation occurs faster in acid media than in neutral or alkaline media (see also "Chemical resistance"). Standard compounds are resistant to pure water to about 70 or 80°C.

Resistance to ionizing radiation

PA 12 is very resistant to ionizing radiation. For example, films made from VESTAMID® L1901 (0.03 to 0.1 mm thick) were subject to gamma rays with a dose rate of 25 kGy (2.5 Mrad), 50 kGy, and 100 kGy. Strain at break was reduced considerably only from a dose of 100 kGy and a slight graying also occurred.

Thicker specimens made from VESTAMID® L1940 were radiated with 400 kGy with no noticeable changes in the mechanical properties.

Radiation crosslinking of PA 12 is possible only with a reactive crosslinker. In addition to a slight increase in the tensile strengths, crosslinking increases the heat deflection temperature considerably extending beyond the melting point of the crystalline proportion.

UV resistance

Exposure to short wave light of wavelengths less than 400 nm results in an accelerated decrease in the molecular mass of the polymers, causing molded parts and semi-finished products to become brittle. Light stabilizers, UV absorbers and/or radical scavengers considerably reduce weathering damage. However, the best protection is provided by suitable grades of carbon black, if blackening is possible. Although light and UV stabilizers improve weathering resistance considerably, they do not achieve the effect of carbon black. Adding pigments can have stabilizing and sensitizing effects. Pigments or carbon black can also have an effect on the mechanical properties.

Accelerated testing is carried out in weathering equipment with and without sprinkling. The spectrum of the radiators that are used largely corresponds to that of sunlight. Preferably, the deterioration of elongation at break or notched impact strength is determined.

4.3 Product properties

Chemical resistance

Interactions between chemicals and polymers can vary considerably. The following cases occur:

- The polymer absorbs the chemical to a certain level, which causes it to swell to a varying degree. This is usually a reversible process. In other words, when the media that is causing the effect is removed, the molded part once again has its original properties, assuming the chemical did not extract soluble additives. The swelling has a softening effect, which reduces tensile strength and increases flexibility and impact strength.

- The chemical acts as a solvent – often only at high temperatures –, at lower temperatures it usually acts only as a strong swelling agent.

- The chemical degrades the polymer; in other words, the molecular mass is reduced. The rate at which this happens is generally very dependent on the temperature. Impact strength and strain at break are reduced and the material is irreversibly damaged.

PA 12 is very resistant to chemically induced stress cracking. Therefore, these cases will not be considered here.

For more detailed information about the effects of various chemicals on our products, we have limited ourselves to typical representatives of chemical groups.
Their effects on hard and plasticized PA 12 are shown in the table below. The chemical resistance of filled and reinforced VESTAMID® L compounds corresponds to that of the hard PA 12 compounds with one difference: swelling, and hence the change in properties, is generally lower, corresponding to the volume of additives.

Chemical resistance of PA 12 compounds
Selection

⊕ resistant
● practically resistant
● little resistant
○ limited resistance
⊖ not resistant

aq aqueous solution
sat saturated at ambient temperature

* Resistance depends on the composition

[1] Boiling point 35 °C
[2] Boiling point 42 °C
[3] Boiling point 46 °C
[4] Boiling point 56 °C

A

	Concentrations %	20 °C	60 °C
Acetone		⊕	⊕
Ad Blue®	32.5	⊕	⊕
Acetic acid (glacial)	100	⊖	⊖
Acetic acid , aq	50	⊖	⊖
	10	⊕	○
Acetic anhydride		⊕	○
Acetic acid butyl ester		⊕	⊕
Acetic acid ethyl ester		⊕	⊕
Accumulator acid	30	●	⊖
Ammonia, gaseous		⊕	⊕
Ammonia, aq	conc.	⊕	⊕
	10	⊕	⊕
Ammonium acetate, aq	any	⊕	⊕
Ammonium carbonate, aq	any	⊕	⊕
Ammonium chloride, aq	any	⊕	⊕
Ammonium nitrate, aq	any	⊕	⊕
Ammonium phosphate, aq	any	⊕	⊕
Ammonium sulfate, aq	any	⊕	⊕
Antifreeze agent (vehicles)*		⊕	⊕
Aqua regia		⊖	⊖

B

Barium salts	any	⊕	⊕
Benzaldehyde		⊖	⊖
Benzaldehyde, aq	sat (0.3)	⊕	⊕
Benzene		⊕	●
Benzoic acid		⊕	⊕
Benzoic acid, aq	sat	⊕	⊕
Borax, aq	sat	⊕	⊕
Boric acid		⊕	⊕
Boric acid, aq	sat (4.9)	⊕	⊕
Brake fluid*		⊕	⊕
Bromine, liquid		⊖	⊖
Bromine vapor	high	⊖	⊖
Bromine water	sat	⊖	⊖
Butane, liquid		⊕	
Butane, gaseous		⊕	⊕
Butyl acetate (Acetic acid butyl ester)		⊕	⊕
n-Butyl alcohol (n-Butanol)		⊕	●

C

Calcium chloride, aq		⊕	●
Calcium nitrate, aq	sat	⊕	●
Carbon disulfide[3)]		⊕	
Caustic soda (sodium hydroxide), aq	50	⊕	⊕
	25	⊕	⊕
	10	⊕	⊕
Chlorine, liquid		⊖	⊖
Chlorine, gaseous, moist	10	⊖	⊖
Chlorine, gaseous, dry		⊖	⊖
Chlorine water	sat	⊖	⊖
Chlorobenzene		●	⊖
Chloroform		●	⊖
Chlorosulfonic acid	100	⊖	⊖
Citric acid	sat	⊕	●
Cresols		⊖	⊖
Cresols, aq	sat (0.25)	●	⊖
Cresol solution		●	⊖
Chrome plating solutions, commercial		⊖	⊖

	Concentrations %	20 °C	60 °C
Chromium salts (di- and trivalent), aq	sat	⊕	⊕
Chromium trioxide, aq	sat	⊖	⊖
Chromium trioxide (Chromic acid)	20	⊖	⊖
Chromosulfuric acid		⊖	⊖
Cyclohexane		⊕	⊕
Cyclohexanol		⊕	⊕
Cyclohexanone		⊕	⊕

D

Decahydronaphtalene		⊕	●
Dibutyl phthalate (plasticizer)		⊕	⊕
Diesel oil see fuels		⊕	⊕
Diethyl ether[1)]		⊕	
Dimethyl formamide		⊕	⊕
1,4-Dioxane		⊕	●

E

Ethanol, not denaturated		⊕	●
Ethanol, liquid, not denaturated	96	⊕	●
	50	⊕	⊕
	10	⊕	⊕
Ethylene chloride		●	○
2-Ethylhexanol		⊕	●

F

Formaldehyde, aq	40	●	⊖
	30	●	⊖
	10	⊕	●
Formic acid	98	○	⊖
	90	○	⊖
	50	○	⊖
	10	⊕	○
Fuels*		⊕	⊕
• regular gasoline		⊕	⊕
• premium gasoline		⊕	⊕
• gasoline E10		⊕	⊕
• diesel fuel		⊕	⊕
• biodiesel fuel		⊕	⊕

G

Gasoline see fuels		⊕	⊕
Glycerol		⊕	⊕
Glycerol, aq	high	⊕	⊕
	low	⊕	⊕
Glycol		⊕	⊕
Glycol, aq	high	⊕	⊕

H

Heating oils*		⊕	⊕
Heptane		⊕	⊕
Hexane		⊕	⊕
Hydraulic fluids*		⊕	⊕
Hydrochloric acid	conc.	⊖	⊖
	10	○	⊖
Hydrofluoric acid	40	⊖	⊖
Hydrogene chloride, gaseous	high	⊖	⊖
	low	●	⊖
Hydrogen peroxide, aq	30	●	○
	10	●	○

	Concentrations %	20 °C	60 °C
Hydrogen peroxide, aq	3	⊕	⊕
Hydrogen sulfide	low	⊕	⊕
I			
Iron salts, aq	sat	⊕	⊕
Isoamyl alcohol		⊕	●
Isooctane		⊕	⊕
Isopropyl alcohol		⊕	●
M			
Magnesium salts, aq	sat	⊕	⊕
Mercury		⊕	⊕
Mercury salts, aq	sat	⊕	⊕
Methanol		⊕	●
Methanol, aq	50	⊕	⊕
Methylene chloride[2)]		○	
Methyl ethyl ketone		⊕	⊕
Mineral oils (free of aromatics)		⊕	⊕
Motor oils (motor vehicles)*		⊕	⊕
N			
Naphthalene		⊕	⊕
Nickel salts, aq	sat	⊕	⊕
Nitric acid	50	⊖	⊖
	25	⊖	⊖
	10	○	⊖
Nitrobenzene		●	●
O			
Octane		⊕	⊕
Oil No 3 acc. to ASTM D 380-59		⊕	⊕
Oleic acid		●	●
Oleum	any	⊖	⊖
Oxalic acid, aq	sat	●	●
Ozone (<0.5 ppm)		⊕	⊕
P			
Palm kernel oil		⊕	⊕
Paraffin oil		⊕	⊕
Paraffin wax		⊕	⊕
Petrol see fuel		⊕	⊕
Petroleum		⊕	⊕
Phenol		⊖	⊖
(aqueous phase)	sat (approx. 9)	●	⊖
(phenolic phase)	sat (approx. 70)	⊖	⊖
Phosphoric acid	sat (86)	⊖	⊖
	50	⊖	⊖
	10	○	⊖
Phosphorus pentoxide		○	⊖
Potassium carbonate (potash)	sat	⊕	⊕
Potassium chlorate, aq	sat (7.3)	●	●
Potassium chloride, aq	sat	⊕	⊕
Potassium dichromate, aq	sat (12)	●	⊖
Potassium hydroxide solution, aq	50	⊕	⊕
	25	⊕	⊕
	10	⊕	⊕
Potassium iodide, aq	sat	⊕	⊕
Potassium nitrate, aq	sat	⊕	⊕
Potassium permanganate, aq	sat (6.4)	○	⊖

	Concentrations %	20 °C	60 °C
Potassium sulfate, aq	sat	⊕	⊕
Propane, liquid		⊕	
Propane, gaseous		⊕	⊕
Pyridine		⊕	
S			
Silicone oils*		⊕	⊕
Silver salts, aq	sat	⊕	⊕
Sodium bicarbonate, aq	sat	⊕	⊕
Sodium bisulfite, aq	sat	⊕	●
Sodium carbonate, aq	sat	⊕	⊕
	10	⊕	⊕
Sodium chlorate, aq	25	●	●
Sodium chloride, aq (table salt)	sat	⊕	⊕
Sodium chlorite, aq	5	●	●
Sodium hydroxide (caustic soda)		⊕	⊕
Sodium hypochlorite, aq	5	●	○
Sodium nitrate, aq	sat	⊕	⊕
Sodium nitrite, aq	sat	●	●
Sodium perborate, aq	sat	⊕	●
Sodium phosphate, aq	sat	⊕	⊕
Sodium sulfate, aq (Glauber salt)	sat	⊕	⊕
Sodium sulfide, aq	sat	⊕	⊕
Sodium sulfite, aq	sat	⊕	⊕
Sodium thiosulfate, aq (fixing salt)	sat	⊕	⊕
Sodium hydroxide (caustic soda), aq	50	⊕	⊕
	25	⊕	⊕
	10	⊕	⊕
Stearic acid		●	●
Succinic acid, aq	sat	●	
Sulfur		⊕	⊕
Sulfur dioxide	low	⊕	⊕
Sulfuric acid	96	⊖	⊖
	50	⊖	⊖
	25	●	⊖
	10	●	⊖
T			
Test fuel		⊕	⊕
Tetrachloromethane		⊕	⊕
Tetrahydrofuran		●	○
Tetrahydronaphthalene		⊕	●
Thiophene		⊕	●
Toluene		⊕	●
Transformer oil*		⊕	⊕
Trichloroethylene		●	○
Turpentine oil		⊕	●
U			
Urea, aq	sat	⊕	⊕
W			
Water		⊕	⊕
X			
Xylene		⊕	●
Z			
Zinc (II) chloride	sat	⊕	⊕

4.4 Product properties

Abrasion and frictional properties

Polyamides are very resistant to abrasion. This can be determined according to DIN 53754 (Taber) or DIN 53516. The test is carried out with grinding abrasion. Harder compounds exhibit more abrasion than soft ones. Abrasion increases again only with very soft compounds.

Abrasion behavior of some VESTAMID® L compounds

	Test method acc. to	
VESTAMID®	DIN 53754 [mg]	DIN 53516 [mm³]
L1600, L1670	10-11	48
L2101F, L2140	12-13	68
L2124	13-16	40
L2128	22-23	-
L1950	12-13	39
L1930	16-19	170
L-GB30	14-15	120

Test specimen conditioned to 23°C, 50% relative humidity. Emery paper was changed after every 100 revolutions.

Coefficient of sliding friction

For bearing and sliding parts, the coefficient of sliding friction is more important than abrasion. This coefficient is dependent on the bearing pressure, the rate of friction, the structure and hardness of the friction surfaces, and the temperature. VESTAMID® L compounds behave well with low to moderate loads. It is important to rub different friction surfaces against each other; the friction coefficient of polyamide against metal is lower than metal against metal. Adding reinforcing material or fillers (glass fibers, graphite) has no effect on sliding friction or abrasion as long as the surface skin of the molded part is not damaged. The additives only have an effect if they come to the surface; for example, with glass fibers, because of the increased abrasion between the sliding surfaces.

Bearings made from PA 12 are suitable for applications where lubricants cause problems. However, it must be pointed out that lubricated bearings are the best solution because they need no maintenance. The high chemical resistance of PA 12 allows almost all lubricants to be used. Lubrication considerably reduces the friction coefficient and almost prevents abrasion.

Finally, we refer to a special use for the high abrasion resistance of VESTAMID® L2101F at very low temperatures: when deep frozen, it makes excellent blasting granules to deflash rubber parts.

5.1 Characterization

Unfilled VESTAMID® L compounds

Physical, thermal and mechanical properties and flammability	Test method	Unit	VESTAMID® L1670	X7377	L1940	L1970
Density	ISO 1183	g/cm³	1.01	1.03	1.01	1.02
Melting temperature DSC, 2nd heating	ISO 11357	°C	178	178	178	178
Temperature of deflection under load						
Method A: 1.8 MPa	ISO 75	°C	50	50	50	50
Method B: 0.45 MPa	ISO 75	°C	120	120	110	110
Vicat softening temperature						
Method A: 10 N	ISO 306	°C	170		170	170
Method B: 50 N	ISO 306	°C	140		140	140
Linear thermal expansion 23-55°C	ISO 11359	10^{-4} K^{-1}	1.5		1.5	1.5
Flammability acc. to UL94						
1.6 mm	IEC 60695		HB		HB	
3.2 mm	IEC 60695		HB		HB	
Water absorption						
23°C, saturation	ISO 62	%	1.4		1.5	
23°C, 50% relative humidity	ISO 62	%	0.7		0.8	0.7
Mold shrinkage						
in flow direction	ISO 294-4, ISO 1874-2	%	0.9		0.85	
in transvers direction	ISO 294-4, ISO 1874-2	%	1.1		1.15	
Tensile test						
Stress at yield	ISO 527-1/-2	MPa	46	53	45	46
Strain at yield	ISO 527-1/-2	%	6	5	5	5
Stress at break	ISO 527-1/-2	MPa		35		51
Strain at break	ISO 527-1/-2	%	>50	>50	>50	>50
Tensile modulus	ISO 527-1/-2	MPa	1400	1700	1350	1600
CHARPY impact strength						
23°C	ISO 179/1eU	kJ/m²	N		N	N
-30°C	ISO 179/1eU	kJ/m²	N		N	N
CHARPY notched impact strength						
23°C	ISO 179/1eA	kJ/m²	4 C	3.5 C	6 C	5 C
-30°C	ISO 179/1eA	kJ/m²	5 C	4.0 C	6 C	6 C
Electrical properties						
Relative permittivity						
23°C, 100 Hz	IEC 60250		3.8		3.8	
23°C, 1 MHz	IEC 60250		2.2		2.5	
Dissipation factor						
23°C, 100 Hz	IEC 60250	10^{-4}	450		450	
23°C, 1 MHz	IEC 60250	10^{-4}	280		310	
Electric strength K20/P50	IEC 60243-1	kV/mm	27		27	
Comparative tracking index						
Test solution A, 100 drops value	IEC 60112		>600		>600	
CTI	IEC 60112		600		600	
Volume resistivity	IEC 60093	Ω cm	10^{15}		10^{15}	
Electrolytic corrosion	IEC 60426	Stage	A1		A1	

N = No break P = Partial break C = Complete break

* Processing conditions according to ISO 294-4, test specimen 60 x 60 x 2 mm

L1950	X7373	LX9009	L2101F	L2140 L2170	L2141 schwarz	LX9001	LX9008	LX9016
1.02	1.01	1.01	1.01	1.01	1.01	1.02	1.01	1.01
178	178	178	178	178	178	177	176	180
	50	51	50	50	50	45	45	45
	130	129	110	110	110	125	125	105
	170	170	170	170	170	175	175	170
	150	140	140	140	140	145	145	130
	1.5		1.5	1.4	1.5		1.4	
	HB		HB	HB	HB		HB	HB
	HB		HB	HB	HB		HB	HB
1.5	1.4		1.6	1.6	1.5		1.4	1.3
0.8	0.7		0.8	0.7	0.7		0.7	
							*	*
	0.95		0.7	0.65	0.7		0.25	1.2
	1.15		1.25	1.25	1.3		1.9	1.2
47	47	41	45	47	46	52	42	35
7.5	5	5	5	5	5	5	5	5
		58				51	48	
>50	>50	>50	>50	>50	>50	>50	>50	>50
1550	1500	1300	1400	1400	1500	1650	1450	1070
N	N	N	N	N	N	N	N	N
N	N	N	N	N	N	N	N	N
5 C	6 C	10 C	32 C	16 C	10 C	6 C	45 P/ C	33 C
	6 C	7 C	9 C	9 C	8 C	6 C	22 C	17 C
	4.2		3.7	3.7	9.7		3.7	3.8
	3.8		3.0	3.0	4.0		2.9	3.0
	750		450	450	2100		520	470
	520		280	260	1100		320	260
	30		29	26	35		26	32
	>600		>600	>600	>600			
	600		600	600	600			
	10^{15}		10^{15}	10^{15}	10^{12}		10^{14}	10^{12}
	A1		A1	A1	A1			

5.2 Characterization

Plasticized VESTAMID® L compounds

Physical, thermal and mechanical properties and flammability	Test method	Unit	VESTAMID® L1723	L2121	L2122	X7393
Density	ISO 1183	g/cm³	1.03	1.02	1.03	1.02
Melting temperature DSC, 2nd heating	ISO 11357	°C	173	176	173	173
Temperature of deflection under load						
Method A: 1.8 MPa	ISO 75	°C	45	45	45	45
Method B: 0.45 MPa	ISO 75	°C	95	110	95	115
Vicat softening temperature						
Method A: 10 N	ISO 306	°C	165	170	165	170
Method B: 50 N	ISO 306	°C	130	130	125	130
Linear thermal expansion 23-55°C	ISO 11359	10^{-4} K^{-1}	1.8	1.6	1.7	1.4
Flammability acc. to UL94						
1.6 mm	IEC 60695		HB	HB	HB	HB
3.2 mm	IEC 60695		HB	HB	HB	HB
Water absorption						
23°C, saturation *[1]	ISO 62	%				
23°C, 50% relative humidity	ISO 62	%	0.5	0.6	0.5	0.6
Mold shrinkage						
in flow direction	ISO 294-4, ISO 1874-2	%	1.65	0.6	0.6	0.8
in transvers direction	ISO 294-4, ISO 1874-2	%	1.5	1.65	1.6	1.35
Tensile test						
Stress at yield	ISO 527-1/-2	MPa	30	35	30	31
Strain at yield	ISO 527-1/-2	%	27	20	26	28
Stress at break	ISO 527-1/-2	MPa				
Strain at break	ISO 527-1/-2	%	>50	>50	>50	>50
Tensile modulus	ISO 527-1/-2	MPa	480	700	490	580
CHARPY impact strength						
23°C	ISO 179/1eU	kJ/m²	N	N	N	N
-30°C	ISO 179/1eU	kJ/m²	N	N	N	N
CHARPY notched impact strength						
23°C	ISO 179/1eA	kJ/m²	24 C	40 C	68 P	115 P
-30°C	ISO 179/1eA	kJ/m²	5 C	7 C	6 C	8 C
Electrical properties						
Relative permittivity						
23°C, 100 Hz	IEC 60250		10	6.5	10	7
23°C, 1 MHz	IEC 60250		3.7	3.4	3.3	4.2
Dissipation factor						
23°C, 100 Hz	IEC 60250	10^{-4}	1600	1900	1900	1900
23°C, 1 MHz	IEC 60250	10^{-4}	1200	550	1000	1100
Electric strength K20/P50	IEC 60243-1	kV/mm	33	34	32	27
Comparative tracking index						
Test solution A, 100 drops value	IEC 60112		>600	>600	>600	>600
CTI	IEC 60112		600	600	600	600
Volume resistivity	IEC 60093	Ω cm	10^{12}	10^{14}	10^{13}	10^{12}
Electrolytic corrosion	IEC 60426	Stage	A1	A1	A1	

N = No break P = Partial break C = Complete break

* Plasticized compounds were not stored in water because of slight plasticizer migration.

X7297	L2124	L2123	X7293	L2128	LX9013
1.02	1.03	1.03	1.02	1.05	1.02
172	171	171	172	164	172
51	45	45	45	40	55
135	90	80	100	70	130
	165	165	165	145	165
	125	120	130	100	130
	1.8	1.8	1.8	1.8	1.6
	HB	HB	HB	HB	HB
	HB	HB	HB	HB	HB
	0.5	0.6	0.5	0.5	0.6
	0.7	0.65	0.65	0.65	0.35
	1.55	1.4	1.35	1.2	1.45
27	26	24	27	18	
35	31	32	32	45	
43					
>50	>50	>50	>50	>50	>50
400	400	370	400	230	410
N	N	N	N	N	N
N	N	N	N	N	N
132 P	150 P	115 P	130 P	N	140 P
6 C	6 C	13 C	7 C	6 C	7 C
	12	10	11	17	12
	3.8	3.6	4.6	3.8	3.4
	1600	2000	2000	3000	5000
	1500	1100	1900	2400	1000
	32	29	30	31	22
	>600	>600	>600	>600	>600
	600	600	600	600	600
	10^{12}	10^{12}	10^{12}	10^{10}	10^{10}
	A1	A1		A1	

5.3 Characterization

Filled, reinforced VESTAMID® L compounds with flame retardant

Physical, thermal and mechanical properties and flammability	Test method	Unit	VESTAMID® L-GF15	L1833	L-GF30	L1930
Density	ISO 1183	g/cm³	1.12	1.17	1.24	1.24
Melting temperature DSC, 2nd heating	ISO 11357	°C	178	178	178	178
Temperature of deflection under load						
Method A: 1.8 MPa	ISO 75	°C	160	160	165	130
Method B: 0.45 MPa	ISO 75	°C	175	175	175	170
Vicat softening temperature						
Method A: 10 N	ISO 306	°C	175	175	175	175
Method B: 50 N	ISO 306	°C	170	175	175	170
Linear thermal expansion 23-55°C	ISO 11359	10^{-4} K^{-1}	0.8	0.7	0.6	0.5
Flammability acc. to UL94						
1.6 mm	IEC 60695		HB	HB	HB	HB
3.2 mm	IEC 60695		V-2	V-2	HB	HB
Water absorption						
23°C, saturation *[1]	ISO 62	%	1.3	1.2	1.1	1.1
23°C, 50% relative humidity	ISO 62	%	0.6	0.6	0.5	0.5
Mold shrinkage						
in flow direction	ISO 294-4, ISO 1874-2	%	0.35	0.2	0.15	0.7
in transvers direction	ISO 294-4, ISO 1874-2	%	0.65	0.65	0.65	0.6
Tensile test						
Stress at yield	ISO 527-1/-2	MPa				69
Strain at yield	ISO 527-1/-2	%				4
Stress at break	ISO 527-1/-2	MPa	95	105	120	60
Strain at break	ISO 527-1/-2	%	6	6	5	10
Tensile modulus	ISO 527-1/-2	MPa	3900	5000	6500	4000
CHARPY impact strength						
23°C	ISO 179/1eU	kJ/m²	75 C	90 C	85 C	70 C
-30°C	ISO 179/1eU	kJ/m²	80 C	95 C	100 C	65 C
CHARPY notched impact strength						
23°C	ISO 179/1eA	kJ/m²	17 C	25 C	23 C	10 C
-30°C	ISO 179/1eA	kJ/m²	11 C	16 C	21 C	11 C
Electrical properties						
Relative permittivity						
23°C, 100 Hz	IEC 60250		4	4.1	4.1	4.1
23°C, 1 MHz	IEC 60250		3.4	3.4	3.4	3.4
Dissipation factor						
23°C, 100 Hz	IEC 60250	10^{-4}	380	370	310	310
23°C, 1 MHz	IEC 60250	10^{-4}	260	260	330	240
Electric strength K20/P50	IEC 60243-1	kV/mm	44	41	44	40
Comparative tracking index						
Test solution A, 100 drops value	IEC 60112		>600	>600	>600	>600
CTI	IEC 60112		600	600	600	600
Volume resistivity	IEC 60093	Ω cm	10^{15}	10^{15}	10^{15}	10^{15}
Electrolytic corrosion	IEC 60426	Stage	A1	A1	A1	

N = No break P = Partial break C = Complete break

* Plasticized compounds were not stored in water because of slight plasticizer migration.

*[2] Processing conditions according to ISO

L-GB30	X7000	X7166	X7167	X7229	LX9104
1.25	1.18	1.06	1.05	1.06	1.12
178	178	178	178	175	175
55	46	50	50	40	49
150	115	140	130	130	127
175		175	175	170	167
155		150	150	150	127
1.3				0.8	1.0
HB	V-0	V-2	V-2	V-2	V-0
HB	V-0	V-2	V-2	V-2	V-0
1.1		1.3	1.5		2.5
0.5		0.6	0.6	0.6	0.7
1.2*[2]	0.94	0.65	0.6	0.55	0.43
1.2*[2]	1.13	0.75	0.95	0.8	0.7
47	37	47	48	36	28
5	5	5	5	17	27
38	28				35
37	>50	>50	>50	>50	>50
2000	1400	1800	1700	1000	750
160 C	N	65 C	N	N	N
160 C		80 C	N	N	N
6 C	7 C	3 C	9 C	11 C	40 P
6 C		5 C	6 C	5 C	5 C
4.1					
3.5	3.9	3.6	3.6	5	3.8
310					
230	500	340	380	1700	1015
31	27	28	28	27	26
>600		>600	>600	>600	>600
600		600	600	600	600
10^{15}	10^{11}	10^{14}	10^{14}	10^{13}	10^{8}
A1			A1		A1

294-4. test specimen 60 x 60 x 2 mm

5.4 Characterization

Permanently antistatic and electrically conductive VESTAMID® L compounds

Physical, thermal and mechanical properties and flammability	Test method	Unit	VESTAMID® L-R3-MHI	L-R4-MHI	L-R7-MHI	L-R9-MHI
Density	ISO 1183	g/cm³	1.1	1.06	1.08	1.08
Melting temperature DSC, 2nd heating	ISO 11357	°C	178	178	178	178
Temperature of deflection under load						
Method A: 1.8 MPa	ISO 75	°C	50	50	50	50
Method B: 0.45 MPa	ISO 75	°C	130	130	130	130
Vicat softening temperature						
Method A: 10 N	ISO 306	°C	175	175	175	175
Method B: 50 N	ISO 306	°C	140	140	140	140
Linear thermal expansion 23-55°C	ISO 11359	10^{-4} K^{-1}	1.8	1.8	1.7	1.7
Flammability acc. to UL94						
1.6 mm	IEC 60695		HB	HB	HB	HB
3.2 mm	IEC 60695		HB	HB	HB	HB
Water absorption						
23°C, saturation	ISO 62	%	1.5	1.5	1.5	1.5
23°C, 50% relative humidity	ISO 62	%	0.8	0.5	0.7	0.7
Mold shrinkage						
in flow direction	ISO 294-4, ISO 1874-2 *²	%	1.45	1.75	1.4	1.4
in transvers direction	ISO 294-4, ISO 1874-2 *²	%	1.55	1.65	1.45	1.45
Tensile test						
Stress at yield	ISO 527-1/-2	MPa	38	36	36	37
Strain at yield	ISO 527-1/-2	%	5	8	6	6
Stress at break	ISO 527-1/-2	MPa		33		
Strain at break	ISO 527-1/-2	%	>50	42	>50	>50
Tensile modulus	ISO 527-1/-2	MPa	1600	1250	1400	1400
CHARPY impact strength						
23°C	ISO 179/1eU	kJ/m²	N	N	N	N
-30°C	ISO 179/1eU	kJ/m²	N	N	N	N
CHARPY notched impact strength						
23°C	ISO 179/1eA	kJ/m²	55 P	55 P	60 P	60 P
-30°C	ISO 179/1eA	kJ/m²	15 C	12 C	12 C	12 C
Electrical properties						
Isolationswiderstand	IEC 60167	Ω	10^4	10^5	10^7	10^9
Volume resistivity	IEC 60093	Ω cm	10^4	10^5	10^7	10^9

N = No break P = Partial break C = Complete break

* Plasticized compounds were not stored in water because of slight plasticizer migration.

L-R3-EI	L-R2-GF25	X7380	LX9112	LX9102
1.06	1.27	1.21	1.12	1.12
178	178	178	176	171
60	170	160	52	55
130	175	175	150	120
175	175	175	174	169
140	170	170	156	136
1.5	1.0	0.4		1.5
HB	HB	HB		HB
HB	HB	HB		HB
1.2	1.2	1.2		
0.5	0.5	0.6		0.5
1.55	0.3	0.25		1.35
1.6	0.85	0.75		1.5
42		97	54	32
9		3.5	4.7	37
36	120	100	43	39
44	5	6	46	>50
1500	6500	5400	2000	640
N	75 C	80 C	N	N
N	70 C	60 C	N	N
21 C	12 C	17 C	3.7	90 P
9 C	11 C	8 C	4.4	5 C
10^3	10^2	10^7	10^6	10^4
10^3	10^2	10^7	10^2	10^4

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