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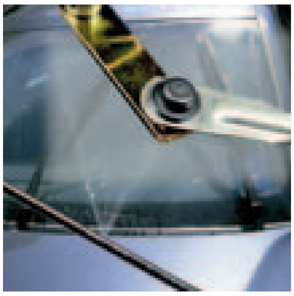

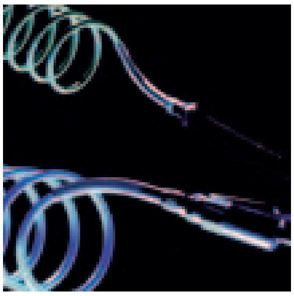

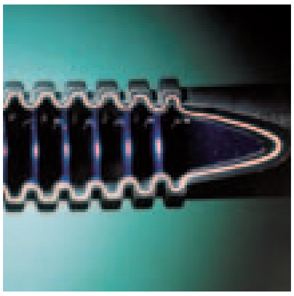

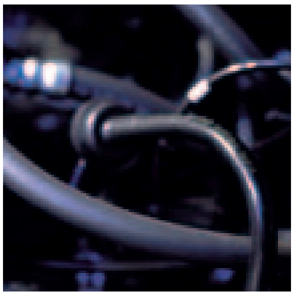

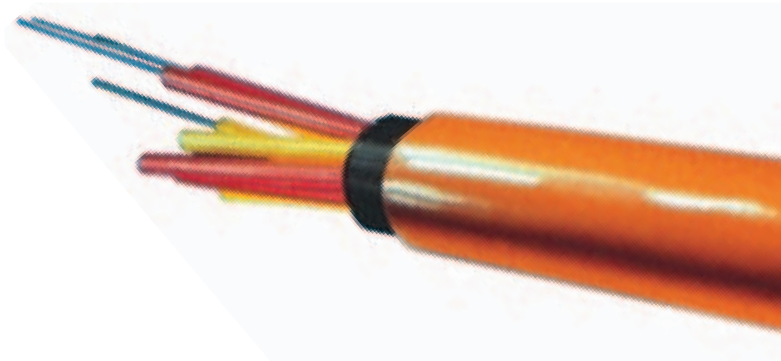

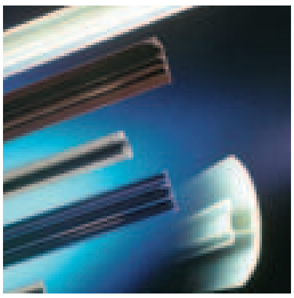

- **Polyamide 12**
  1. Synopsis of Polyamide 12 Grades and Properties
  2. Comparative Tables of Grades
- Polyamide 12 Elastomers
- Polyamide 612
- Handling and Processing of VESTAMID

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VESTAMID Polyamid 12

Introduction

Degussa's High Performance Polymers Business Unit manufactures a range of compounds of polyamide 12 (PA 12), polyamide 612 (PA 612) and polyamide elastomers (PEBA[1]) which are supplied under the registered trademark VESTAMID.

The PA 12 compounds are described in this part of the VESTAMID brochure, whereas the other two product families are the subject of the brochures "Polyamide 12 Elastomers" and "Polyamide 612", respectively.
For information about the processing of the polyamide compounds, refer to VESTAMID bochure "Handling and Processing of VESTAMID."

Starting from butadiene, Degussa manufactures laurolactam, the monomer for PA 12, in a multi-step process, which is then converted by means of a polycondensation reaction into PA 12:

$$-[NH-(CH_2)_{11}-CO]_n-NH-(CH_2)_{11}-CO-$$

Several well defined cyclic intermediates are commercialized as a feedstock for the synthesis of organic substances, too.

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 and increase the strength, the melting point and the chemical resistance. These properties are the characteristics for all semicrystalline polyamides.

The concentration of amide groups is the lowest in PA 12 compared to any other commercially available polyamide, and this determines the specific properties of PA 12. Hence, PA 12 is distinguished for its properties as follows:

- the lowest water absorption of all commercially available polyamides, resulting in properties which vary little with changing humidity and in moldings with virtually unchanged dimensions
- exceptional impact and notched impact strengths, in both dry as molded state and at temperatures well below the freezing point
- good to excellent resistance against greases, oils, fuels, hydraulic fluids, various solvents, salt solutions and etc.
- exceptional resistance to stress cracking, including metal parts encapsulated by injection molding or embedded
- exceptional abrasion resistance
- low coefficient of sliding friction, in dry running against steel, polybutylene terephthalate, polyacetal, and other materials
- noise and vibration damping properties
- superb fatigue resistance under high frequency cyclical loading condition
- high processability

The properties of PA 12 compounds can be modified to suit the requirements of many applications by incorporating various additives such as stabilizers, plasticizers, reinforcements, and fillers.

Many of the PA 12 compounds are suitable especially for the injection molding of precision parts; others have been developed specifically for the extrusion process.

Like all high-performance plastics by the High Performance Polymers Business Unit, VESTAMID compounds satisfy the highest quality standards. Our quality assurance system is certified according to ISO 9001 and QS 9000. Throughout the years, numerous customers have conducted quality assessments and concluded that the Quality Management System is highly recommendable.

[1] PEBA = Poly Ether Block Amide, according to ISO 1043 or DIN 7728, both part 1.

1 Synopsis of Polyamide 12 Grades and Properties

1.1 Synopsis of grades

The PA 12 compounds by High Performance Polymers cover a wide variety of products designed to meet different requirements from processors and end-users. The following tables give a characterization of the most important resins together with their typical applications. Detailed technical information is given in the comparative property tables in Section 2 for most compounds. Specific data sheets for the other compounds can be requested from the Technical Marketing Department of High Performance Polymers.

Other properties of VESTAMID compounds and material information on the other products of the High Performance Polymers Business Unit are contained in the plastics database CAMPUS® [2)], which is updated regularly. You will find CAMPUS on the Internet at www.degussa-hpp.com

1.1.1 Nomenclature

VESTAMID compounds are divided by name into commercial and development products. The commercial products are supplied with a defined formulation and a broadly accepted constant quality, identified by a systematic nomenclature. The formulation of development grades can be changed in order to optimize its performance for any specific application (see 1.1.2).

Numerous commercial compounds are identified according to the following system: The registered trademark VESTAMID is followed by an upper-ease letter, indicating the polyamide base and a four digit number, e.g., VESTAMID L2140. L indicates laurolactam, the monomer of PA 12. The first two digits represent the ten-fold product of the relative solution viscosity of the base polymer, measured according to ISO 307 solved in m-cresol. The relative solution viscosity[3)], in the above example 2.1, together with the knowledge of the concentration (approximately 0.5 g/100 ml), allows the viscosity number to be calculated as 220 ml/g.

Degussa prefers solution viscosity as the characterization for the molecular mass of polyamides. Melt rates (MFR; MVR) are not specified, because polyamides have to be considered as a kind of "living" polymer under the test conditions; so even minimal water contents of the compound might lead to widely scattering, non reproducible values of melt rates, whereas a similar concentration of moisture would not affect the solution viscosity at all. For a particular grade, the higher the first two numbers, the higher the molecular mass and the melt viscosity are.

The third digit indicates a modification by means of an additive, and signifies the following:

0 No additives – basic polyamides. Basic products differ only in their molecular mass, e.g., L1600 and L1901.

2 Plasticized products, which additionally contain stabilizers, e.g., L2124 and L2128.

3 Products containing reinforcements or fillers, such as glass fibers or glass microbeads and stabilizers, e.g., L1930. Besides the tensile strength, reinforcement with carbon or glass fibers also increases the heat deflection temperature under load. This method of modification has been partially transferred to the new nomenclature (see next page).

4 Product containing stabilizers and if necessary, processing aids, e.g., L1940 or L2141.

5 Product containing molybdenum disulphide and stabilizers, e.g., L1950.

6 Products containing graphite and stabilizers, e.g., L1660.

[2] Campus® is the registered trademark of CWF GmbH/Frankfurt (Main).

[3] Relative solution viscosity: $\eta_{rel} = t/t_0$; t = flow time of solution and t_0 = flow time of the pure solvent.
Viscosity number: VN = (η_{rel} -1) /c, where c is the concentration in g/100 ml

The fourth digit is for differentiation purposes within a group of modifications. VESTAMID L2140 and L2141 differ only in the nature of stabilization. For the plasticized compounds, the level of plasticizer is denoted by an increasing fourth digit.

A new nomenclature has been introduced, which is based on now commonly used ISO 1874-1. It offers more possibilities to differentiate between related compounds, e.g., those containing fillers.

The letters used here have the following meaning:

B	spherical shaped fillers – microbeads
C	carbon, graphite
D	powdered or milled additives
F	fiber
FR	flame retardant
G	glass
(H) I	(high) impact modified
P	plasticized
R	surface resistance/permanently antistatic
E	extrusion grade
M	injection molding grade

The concentration for a filler or reinforcement is indicated in weight percent after its identification letter. For permanently antistatic grades, the letter “R” is followed by the exponent of the average surface resistance, e.g., R3 means a surface resistance of 10^3 Ohms.

1.1.2 Development products

Development products are usually designed for a specific application. When the product is introduced into the market, findings and feedback from the customers improve work. Consequently, a change in the formulation or manufacturing process may lead to some slight changes in the products properties. The customers will be informed immediately about any measures or modifications to the material composition, and how the influence is onto the quality or specification of the product itself.

PA 12 development grades are identified by the letters LX or X, followed by a four digit registration number. These four digits, however, do not contain any information, neither on the composition nor the properties.

1.1.3 Supply and coloring

VESTAMID compounds are delivered as a dry, ready-to-process granulate in moisture-proof bags with a net weight of 25 kg. By mutual agreement we also deliver VESTAMID in 1,000 kg octabins. The storage time of unopened packaging is almost unlimited under ordinary storage conditions, unless the packaging is damaged. The storage temperature should not exceed 45 °C, especially in the case of plasticized resins. If plasticized compounds are subjected to higher temperatures for longer periods, plasticizers may migrate on the surface of the granules to some extent.

Like all other semicrystalline polyamides, VESTAMID appears colorless in the melt and whitish opaque in the solid state (natural color). VESTAMID may be colored upon request, unless the limitation is imposed by the presence of special additives. Most compounds are supplied either in natural or black color. Others will exhibit the inherently specific color due to the additive used (e.g. , permanently antistatic compounds).

Some compounds are supplied in a range of standard colors. Special colors are available for large orders. In all cases, lead- and cadmium-free pigments are used. Additional information can be obtained from the Sales Department of High Performance Polymers.

VESTAMID compounds can also be colored during processing. The preferred method is the application of a pigment concentrate based on PA 12. Dry coloring by tumbling with finely powdered pigments is another possibility, but is inconvenient. Pneumatic conveyance is then ruled out. The use of color pastes or color concentrates consisting of a “neutral” base can lead to the incompatibility with PA 12 and hence results in poor parts properties (e.g., inferior weld line strength or streakiness); preliminary testing for compatibility is therefore absolutely essential.

For additional information and support, please contact our Technical Marketing Department.

1.1.4 Tables of characteristics and applications

Table 1: Unfilled PA 12 compounds

VESTAMID	Foot-notes	Designation acc. to ISO 1874-1:	Characterization	Processing	Tensile modulus [MPa]	Applications examples
L1600	1	PA12, XN, 12-010	Basic PA12 polymer, low-viscosity	I, E, C	1300	Manufacturing of additive batches for coloring, stabilization or processing aids
L1700	1	PA12, XN, 14-010	Basic PA12 polymer, low-viscosity	I, E, C	1300	Manufacturing of additive batches for coloring, stabilization or processing aids
L1901	1	PA12, XN, 18-010	Basic PA12 polymer, medium-viscosity	I, E, C	1300	Manufacturing of additive batches for coloring, stabilization or processing aids
L1670	2	PA12, KHL, 12-010	Low-viscosity, heat- and light-stabilized, with processing aid	I, E	1400	Wire insulations, coils, secondary coating of optical fibers
X7377 sw	1,3	PA12, HHL, 12-020	Low-viscosity, heat- and light-stabilized, adhesion promoter	E	1650	Extrusion coating of metal tubing
L1940	2	PA12, KH, 18-010	Medium-viscosity, heat-stabilized, with processing aid	I, E	1400	Loose tubing for optical fibers, sheathing for steel wire cables
X7373	2	PA12, MHR,18-010N	Medium-viscosity, heat-stabilized, nucleated, very short cycle time	I	1500	Filter housings, valve housings, bushings
L1950 sw	1,3	PA12, MHS, 18-020	Medium-viscosity, heat-stabilized, reduced friction and wear trough molybdenum disulphide modification	I	1550	Guide rails, slide bushings, trip cams
L2101F	2	PA12, F, 22-010	High-viscosity, steam sterilizable	E	1400	Films for packaging applications, catheter
L2106F	2	Not applicable	High-viscosity, improved transparency, modified by co-monomers	E	1300	Flexible tubular film for sausage casings
L2140	2	PA12, EHL, 22-010	High-viscosity, heat- and light-stabilized, with processing aid	E	1400	Fuel lines, tubing for car window lifts, sheathing for steel cables, semi-finished articles
L2170	2	PA12, EHL, 22-010	High-viscosity, heat- and highly light-stabilized, with processing aid	E	1400	UV-stable and termite-resistant cable sheathing
L2141 sw	2, 3	PA12, EHL, 22-010	High-viscosity, higher heat stability than L2140, light-stabilized, with processing aid	E	1500	Tubing for hydraulic clutches, vacuum lines
LX9008	2	PA12-HI, EHL, 22-010	High-viscosity, heat- and light-stabilized, impact-modified, excellent long-term heat resistant	E	1450	Tubing for diesel fuel lines permanently exposed to higher temperatures

1) Specific data sheet available upon request
2) For detailed data refer to Section 2, "Comparative Tables of Grades"
3) sw = black

I = Injection molding
E = Extrusion
C = Compounding
R = Rotational molding

Table 2: Plasticized PA 12 compounds

VESTAMID	Foot-notes	Designation acc. to ISO 1874-1:	Characterization	Processing	Tensile modulus [MPa]	Applications examples
L1723	2	PA12-P, MHLR, 14-004	Low-viscosity, plasticized, heat-stabilized, with mold release	I	450	Cable ties, fastening elements
L2121	2	PA12-P, EHL, 22-007	High-viscosity, plasticized, heat- and light-stabilized, with processing aid	E	700	Fuel, vacuum and hydraulic lines, steel cable sheathing
L2122	2	PA12-P, EHL, 22-005	High-viscosity, plasticized, heat- and light-stabilized, with processing aid	E	490	Fuel, vacuum and hydraulic lines, steel cable sheathing
X7393	2	PA12-HIP, EHL, 22-005	High-viscosity, plasticized, heat- and light-stabilized	E	570	Air brake tubing acc. to DIN 73378/74324 and ISO 7628, Type PA 12-PHLY, for higher working pressure
L2124	2	PA12-P, EHL, 22-004	High-viscosity, plasticized, heat- and light-stabilized, with processing aid	E	400	Fuel, vacuum and hydraulic lines, sheathing of steel cables
L2123	2	PA12-P, EHL, 22-004	High-viscosity, plasticized, heat- and light-stabilized, with processing aid, increased low-temperature impact strength	E	370	Tubing and coils for air brake lines, with high cold impact strength, meets SAE J844, ISO 7628, and DIN 74323/74324
X7293	2	PA12-HIP, EHL, 22-004	High-viscosity, plasticized, heat- and light-stabilized, with processing aid, increased low-temperature impact strength	E	400	Fuel, vacuum and hydraulic lines; tubing for air brake lines, meets DIN 73378, 74324, ISO 7628, SAE J844
LX9013	2	PA12-HIP, EHL, 22-004	High-viscosity, plasticized, heat- and light-stabilized, impact-modified, excellent long-term heat resistant	E	400	Flexible tubing for diesel fuel lines permanently exposed to higher temperatures
L2128	2	PA12-P, EHL, 22-002	High-viscosity, highly plasticized, heat- and light-stabilized, with processing aid	I, E	230	Very flexible tubing and hose for pneumatic systems, sheathing of cables

2) Refer to Section 2, “Comparative Tables of Grades” for details

I = Injection molding
E = Extrusion
R = Rotational molding

Table 3: Filled, reinforced and flame retardant containing PA 12 compounds

VESTAMID	Foot-notes	Designation acc. to ISO 1874-1:	Characterization	Processing	Tensile modulus [MPa]	Applications examples
L-GF15	2	PA12, MHR, 16-040, GF15	15% chopped strands, medium-viscosity, heat-stabilized, with processing aid	I	3900	Gear box housing for electric car window lifts
L1833	2	PA12, MHR, 16-050, GF23	23% chopped strands, medium-viscosity, heat-stabilized, with processing aid	I	5000	Quick connectors for fuel lines
LX9105	2	PA12, MH, 18-050, GF23	23% chopped strands, medium-viscosity, heat-stabilized, excellent long-term heat resistant	I	5300	Quick connectors for diesel fuel line systems exposed to high thermal loads
L-GF30	2	PA12, MHR, 18-070, GF30	30% chopped strands, medium-viscosity, heat-stabilized, with processing aid	I	6500	Bearing cups for windshield wipers
LX9111	2	PA12, MH, 16-070, GF30	30% chopped strands, medium-viscosity, heat-stabilized, long-term heat resistant	I	6500	Quick connectors for diesel fuel line systems exposed to high thermal loads
L1930	2	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, parts of fittings
L-GB30	2	PA12, MHR, 16-020, GB30	30% glass microbeads, 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
L-CF15 sw	2,3,5	PA12, MHR, 16-080, CF15	15% carbon fibers, medium-viscosity, heat-stabilized, with processing aid	I	8000	Applications for sports gear, very stiff housings, medical components
X7166	2	PA12, KFH, 12-020	Low-viscosity resin with flame retardant, free of halogen and phosphorus, UL 94-V0/V2, with processing aid	I, E	1800	Wire insulation
X7167	2	PA12, EFH, 22-020	High-viscosity resin with flame retardant, free of halogen and phosphorus, UL 94-V0/V2, with processing aid	E	1700	Profiles for interior trim in aircraft
X7229	2	PA12-P, EFH, 22-010	Plasticized, high-viscosity resin with flame retardant, free of halogen and phosphorus, UL 94-V2, meets FAR 25.853b	E	1000	Profiles, tubes
LX9104	1	PA12-HIP, EFH, 22-010	Plasticized, high-viscosity resin with flame retardant, free of halogen, UL 94-V0, increased low-temperature impact strength	E	800	Profiles, (corrugated) tubes

1) Specific data sheet available upon request
2) For detailed data refer to Section 2, "Comparative Tables of Grades"
3) sw = black
5) Permanently antistatic, refer to Table 4

I = Injection molding
E = Extrusion

Table 4: Permanently antistatic and electrically conductive PA 12 compounds

VESTAMID	Foot-notes	Designation acc. to ISO 1874-1:	Characterization	Processing	Tensile modulus [MPa]	Insulation resistivity 6) [Ω]	Applications examples
L-R1-MHI sw	2, 3	PA12-HI, MHZ, 16-020	Medium-viscosity, heat- and light-stabilized, increased low-temperature impact strength, with processing aid	I	1600	10^1	Antistatic and electrically conductive moldings or extrudates for use in areas prone to explosions such as coal mining and other industries; e.g., housings for explosion-protected measuring equipment or for electric switches, ventilation fans for electric motors, chair castors, loud-speaker boxes, telephone and radio equipment, profiles for guide rails in assembly lines in the electronics industry. Also with electric shock protection.
L-R3-MHI sw	2, 3	PA12-HI, MHZ, 16-020	Medium-viscosity, heat- and light-stabilized, increased low-temperature impact strength, with processing aid	I	1600	10^4	
L-R4-MHI sw	2, 3	PA12-HI, MHZ, 16-010	Medium-viscosity, heat- and light-stabilized, increased low-temperature impact strength, with processing aid	I	1250	10^5	
L-R7-MHI sw	2, 3	PA12-HI, MHZ, 16-010	Medium-viscosity, heat- and light-stabilized, increased low-temperature impact strength, with processing aid. Especially designed for parts meeting DIN EN 50014	I	1400	10^6–10^9	
L-R9-MHI sw	2, 3	PA12-HI, MHZ, 16-010		I	1400	10^8–10^{11}	
X3500 sw	1, 3	PA12-HIP, MHZ, 16-007	Medium-viscosity, heat- and light-stabilized, plasticized, increased low-temperature impact strength	I	700	10^4–10^7	
L-R3-EI sw	2, 3	PA12-HI, EHZ, 22-010	High-viscosity, heat- and light-stabilized, increased low-temperature impact strength, with processing aid	E	1500	10^3	
L-R3-EP sw	2, 3	PA12-P, EHZ, 22-007	High-viscosity, plasticized, heat- and light-stabilized	E	800	10^3	
L-R2-GF25 sw	2, 3	PA12, MHZ, 18-060, GF25	Medium-viscosity, 25% chopped strands, heat- and light-stabilized	I	6500	10^2	
L-CF15 sw	2, 3, 6	PA12, MHR, 16-080, CF15	15% carbon fibers, medium-viscosity, heat-stabilized, with processing aid	I	8000	10^4	
X7380 sw	2, 3, 7	PA12-HI, MHZ, 16-050, GF23	Medium-viscosity, 23% chopped strands, heat- and light-stabilized, increased impact strength	I	5400	10^7	Quick connectors in conductive fuel lines
LX9107 sw	2, 3	PA12, MHLZ, 16-070	Reinforced, medium-viscosity, conductive, heat- and weathering-stabilized	I	9500	10^4	Conductive quick connectors
LX9102 sw	2, 3, 8	PA12-HIP, EHLZ, 22-005	Conductive high-viscosity, plasticized, heat- and light-stabilized, with processing aid, increased low-temperature impact strength	E	600	10^4	Electrically conductive tubings

1) Specific data sheet available upon request
2) For detailed data refer to Section 2, "Comparative Tables of Grades"
3) sw = black
6) Determined on test specimen acc. to DIN EN 50014; corresponds to R_{OE} acc. to DIN 53 482: 1983
7) Refer to Table 6
8) Refer to Table 5

I = Injection molding
E = Extrusion

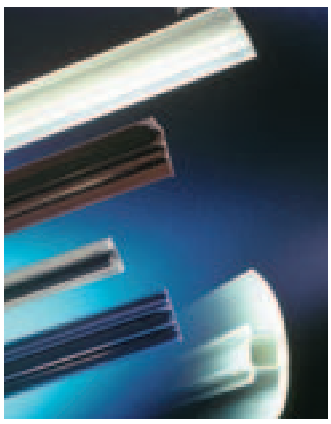


Table 5: Special PA 12 compounds for the extrusion of multilayer tubing (MLT) for fuel lines [9)]

VESTAMID	Foot-notes	Designation acc. to ISO 1874-1:	Characterization	Tensile modulus [MPa]	Applied in multilayer tubing system of type
X7293		PA12-HIP, EHL, 22-004	High-viscosity, plasticized, heat- and light-stabilized,	400	140, 2000
LX9002		PA12-HIP, EHL, 22-004	with processing aid, increased low-temperature	400	2030, 2040
LX9010		PA12-HIP, EHL, 22-004	impact strength	400	1000
X7395 sw	3	PA12-HIP, EHLZ, 22-005	Electrically conductive, high-viscosity, plasticized,	580	2040.1, inner layer
LX9102 sw	3	PA12-HIP, EHLZ, 22-005	heat- and light-stabilized, with processing aid,	600	2040.2, inner layer
			increased low-temperature impact strength		
LX9109 sw	3, 9	PA12-HIP, EHLZ, 22-007	High-viscosity, plasticized, conductive, heat- and weathering-stabilized	650	140.3
X7344		Not applicable	Adhesion resin	–	2000

3) sw = black
9) Specific product information and data sheets of MLT systems and resins available upon request

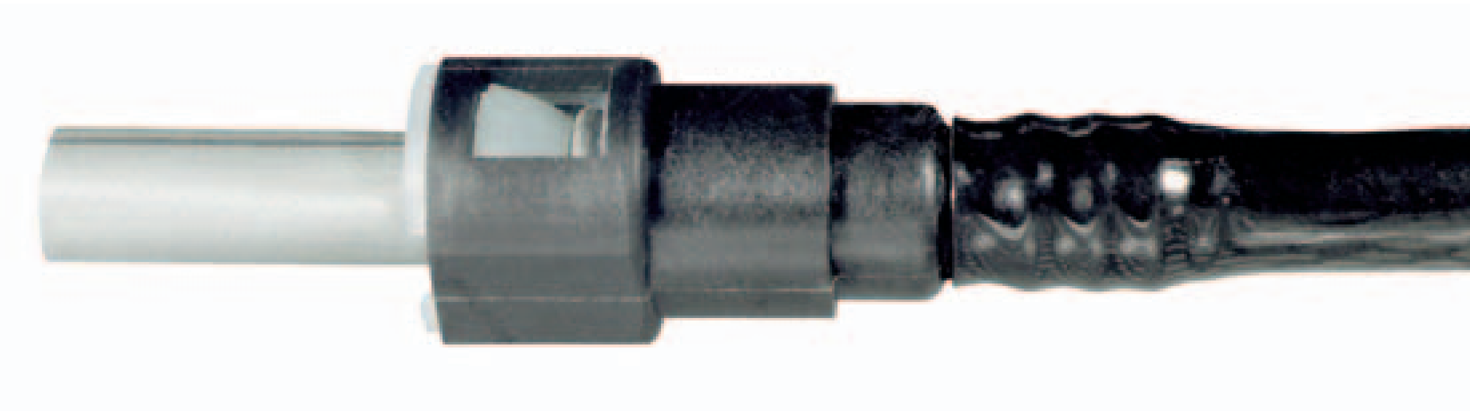


Table 6: Special PA 12 compounds for the manufacture of connectors for fuel and vapor lines or other automotive tubing applications

VESTAMID	Foot-notes	Designation acc. to ISO 1874-1:	Characterization	Tensile modulus [MPa]	Applications examples
X7373	2	PA12, MHR,18-010N	Medium-viscosity, heat- stabilized, nucleated, very short cycle time	1500	Filter housings, valve housings, bushings, tubing connectors
L1833	2	PA12, MHR, 16-050, GF23	23% chopped strands, medium-viscosity, heat-stabilized, with processing aid	5000	Quick connectors for mono and multilayer fuel lines
L-GF30	2	PA12, MHR, 18-070, GF30	30% chopped strands, medium-viscosity, heat-stabilized, with processing aid	6500	Quick connectors for mono and multilayer fuel lines
X7380 sw LX9106 sw	2, 3 1, 3	PA12-HI, MHZ, 16-050, GF23	Medium-viscosity, 23% chopped strands, heat- and light-stabilized, increased impact strength	5400	Quick connectors for electrically MLT types 140, 2040

1) Specific data sheets available upon request
2) For detailed data refer to Section 2, "Comparative Tables of Grades"
3) sw = black

1.2 General properties

1.2.1 Physiological and toxicological evaluation

The Environment, Health & Safety Department, which is responsible for the High Performance Polymers Business Unit, provides general information on the toxicological properties of VESTAMID compounds and relevant analysis pertaining to their contact with foodstuffs. The department is also responsible for providing information about product safety and producing the EC Safety Data Sheets for VESTAMID. Please direct all questions on the subject to our Technical Marketing Department.

With the harmonization of European laws and ordinances, new regulations have come into effect regarding plastics intended to come into contact with foodstuffs. Our basic VESTAMID grades from our PA 12 range have been approved by the European Union for direct contact with foodstuffs, since laurolactam, the fundamental monomer of VESTAMID, was positively listed in EU Directive 2002/72/EC. It imposed a migration value limit of 5 mg per kilogram for laurolactam, which must be tested on the finished article itself and be kept within limits there.

The European Union is not yet finished with its survey of plastics additives. Here, one must fall back on national regulations. Thus, in Germany, the recommendations of the Federal Institute for Consumer Health Protection and Veterinary Medicine (BgVV) must also be taken into account. The BgVV recommendations will be valid until European regulations cover plastics additives.

In accordance with 21CFR, §177.1500, "Nylon Resins", US FDA (Food and Drug Administration) approval for nylon-12 is only valid for films up to a thickness of 0.0016 inches (i.e., 40 µm). This approval covers the basic products L1600, L1800, L1901, L2101F, and L2140B. However, the restrictions stated in specification b(9) (e.g., non-alcoholic food or beverages; heat sterilization at temperature not exceeding 120 °C) have to be observed.

For medical applications, the European approval procedure is laid down in Directive 93/42/EEC. The national implementation of this Directive into German law is the *Medizinproduktegesetz* (Medical Products Act) of August 1994. The detailed procedure to be followed is described in the pertinent international and national standards (e.g., ISO 10993, DIN EN 30993-1). The DAB monographs (German Pharmacopoeia, current edition) or those of the Eur. Pharmacopoeia (current edition 1998) can be used as supplementary regulatory works to make the decision in special cases.

In cases of doubt, the moldings or semi-finished products must be investigated by the manufacturer or user, taking the relevant conditions of use into consideration. Our Technical Marketing Department can provide you information about its experiences with various approval processes.

1.2.2 Environment and ecological safety

VESTAMID compounds are non-hazardous and not harmful to water. They are not subject to any particular safety regulations. Disposal can be done by land filling or incinerating together with normal household rubbish, provided that local ordiances permit this. Further information can be obtained from the Material Safety Data Sheet for VESTAMID. Reprocessing is however preferable and is also of interest for economic reasons.

No dangerous by-products are formed if VESTAMID is processed properly (see brochure "Handling and Processing of VESTAMID"). Care should be taken, however, to ventilate the working area properly as it is required when processing thermoplastics—especially for compounds containing flame retardants or plasticizers.

Compounds containing flame retardants do not contain any brominated biphenyls or diphenylethers. In addition, grades with flame retardants free of halogen or phosphorous compounds can be supplied.

No pigments or additives containing cadmium are used.

Degradation of the material during processing is shown by a discoloration of the melt. Degraded material should be quickly removed from the machine and cooled under water in order to minimize any troublesome odors or fumes.

Most VESTAMID grades can burn. At melt temperatures above 350 °C, flammable gases will be released. Combustion in excess air produces CO, CO_2, H_2O and nitrogen containing compounds as end products. Since the spectrum of crack and combustion products is highly dependent on the combustion conditions, it is not possible to make any general statements here.

1.2.3 Short term influence of temperature

An initial overview of the temperature dependence of the mechanical properties of rigid, (i.e., non-plasticized, non-reinforced) VESTAMID compounds can be obtained from the curves for storage modulus and loss factor, tan δ, as derived from torsional oscillation analyses (refer to Figures 1 and 2). The Figures 3 and 4 show the thermal expansion coefficients of a basic product and compare them with a plasticized and a fiberglass-reinforced or milled-fiberglass-reinforced compound.

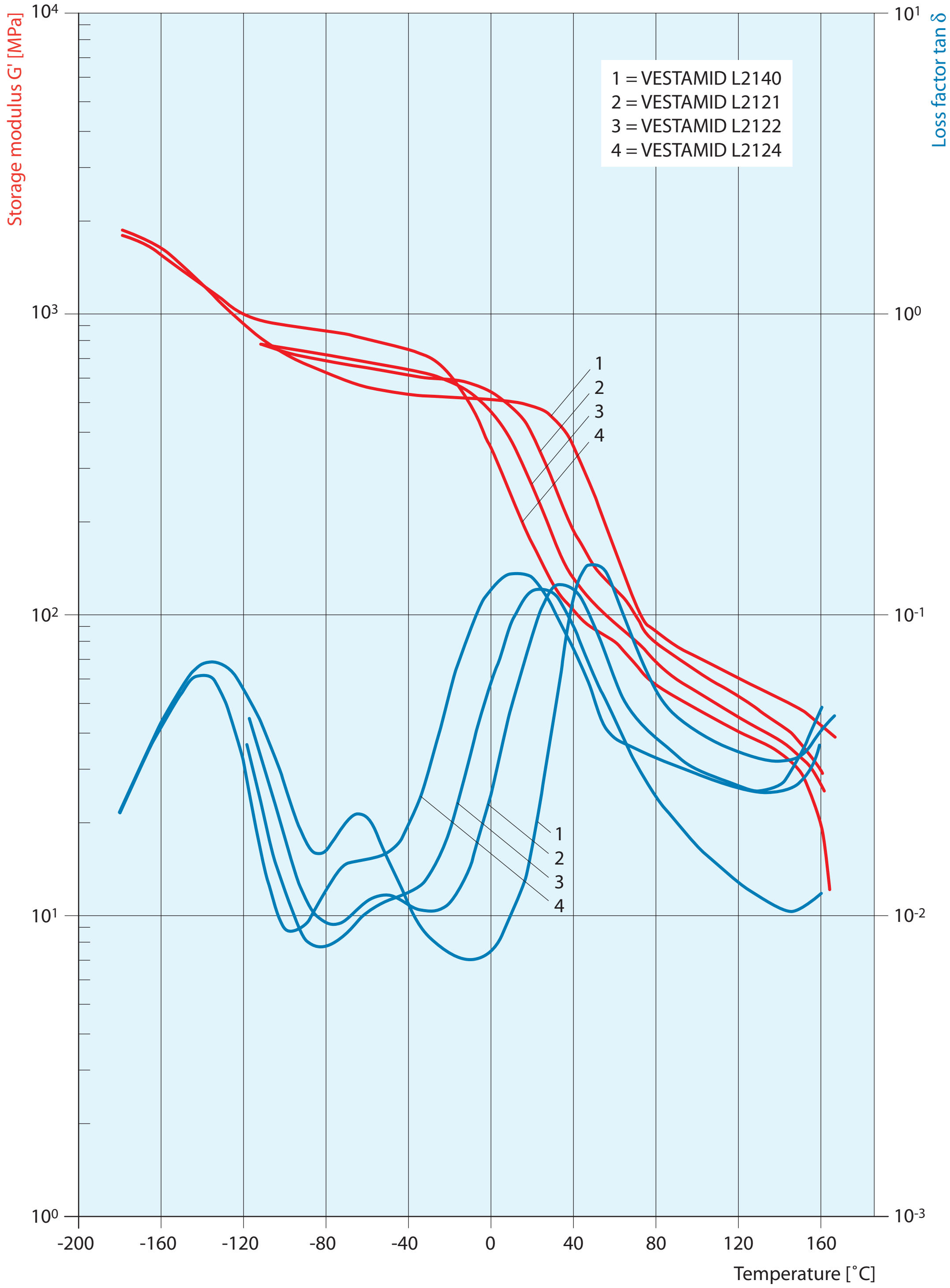


Figure 1: Storage modulus G´ and loss factor tan δ as a function of temperature acc. to ISO 6721

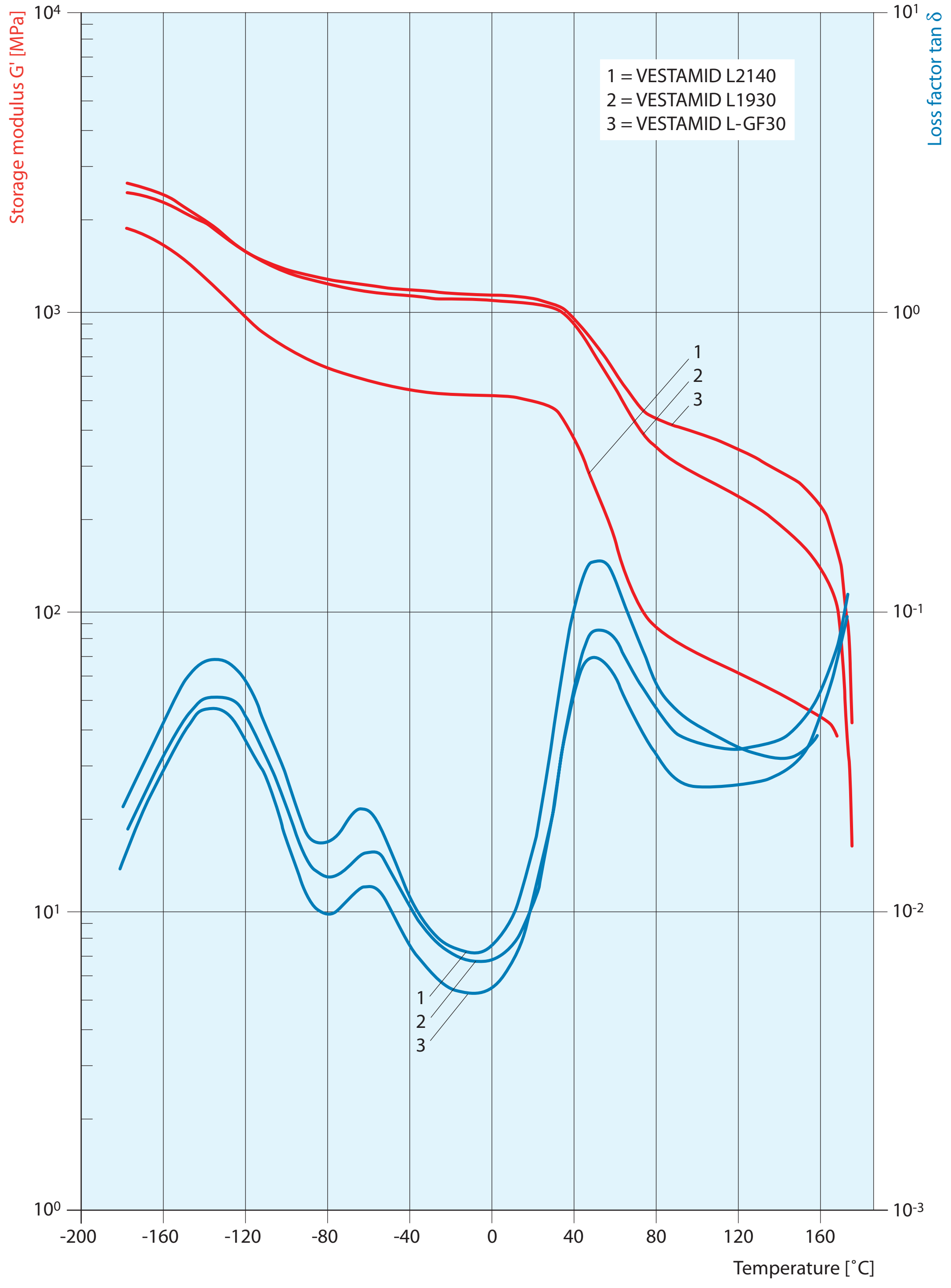


Figure 2: Storage modulus G´ and loss factor tan δ as a function of temperature acc. to ISO 6721

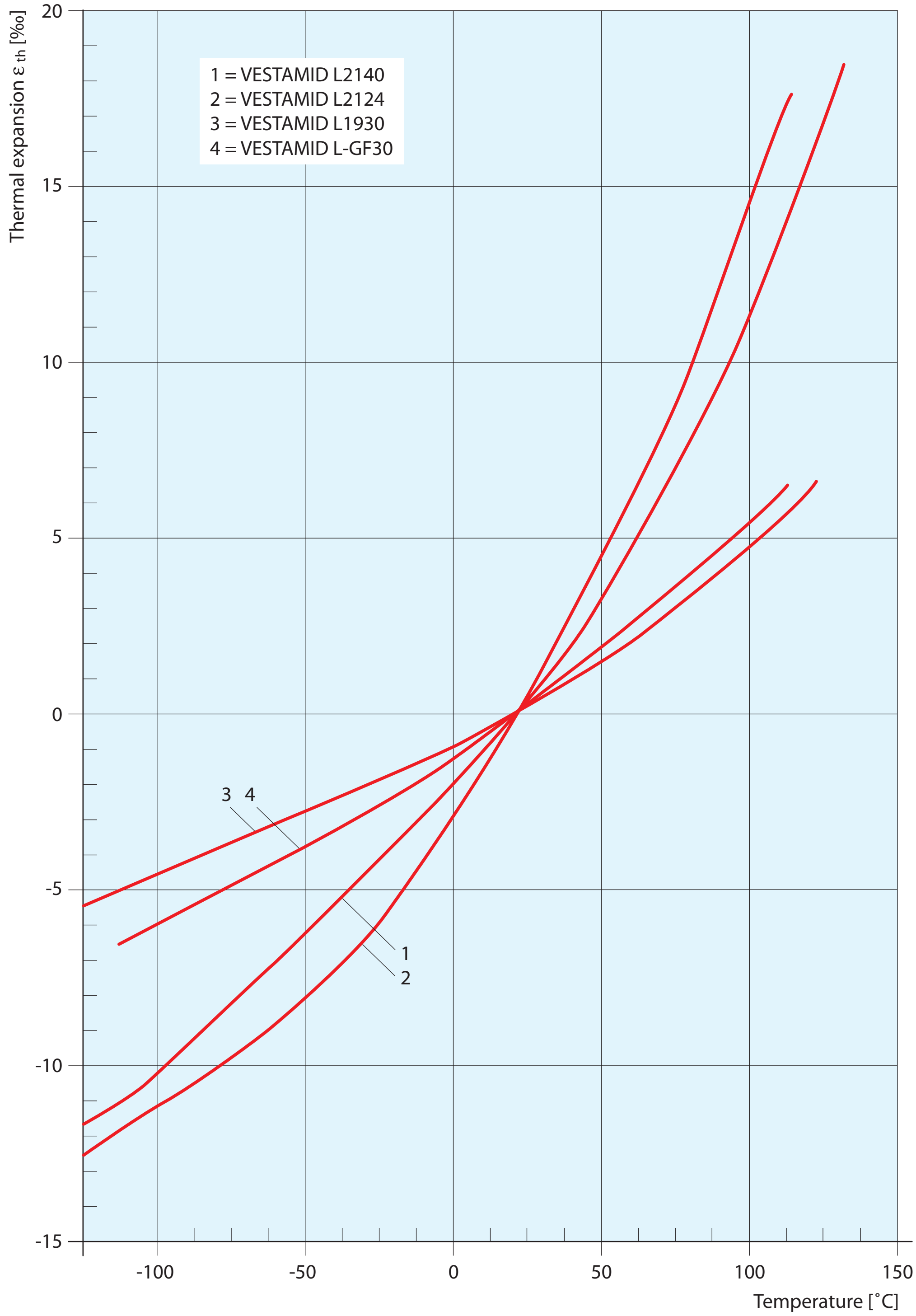


Figure 3: Thermal expansion acc. to ISO 11359
Molded test specimens of 45 x 15 x 10 mm

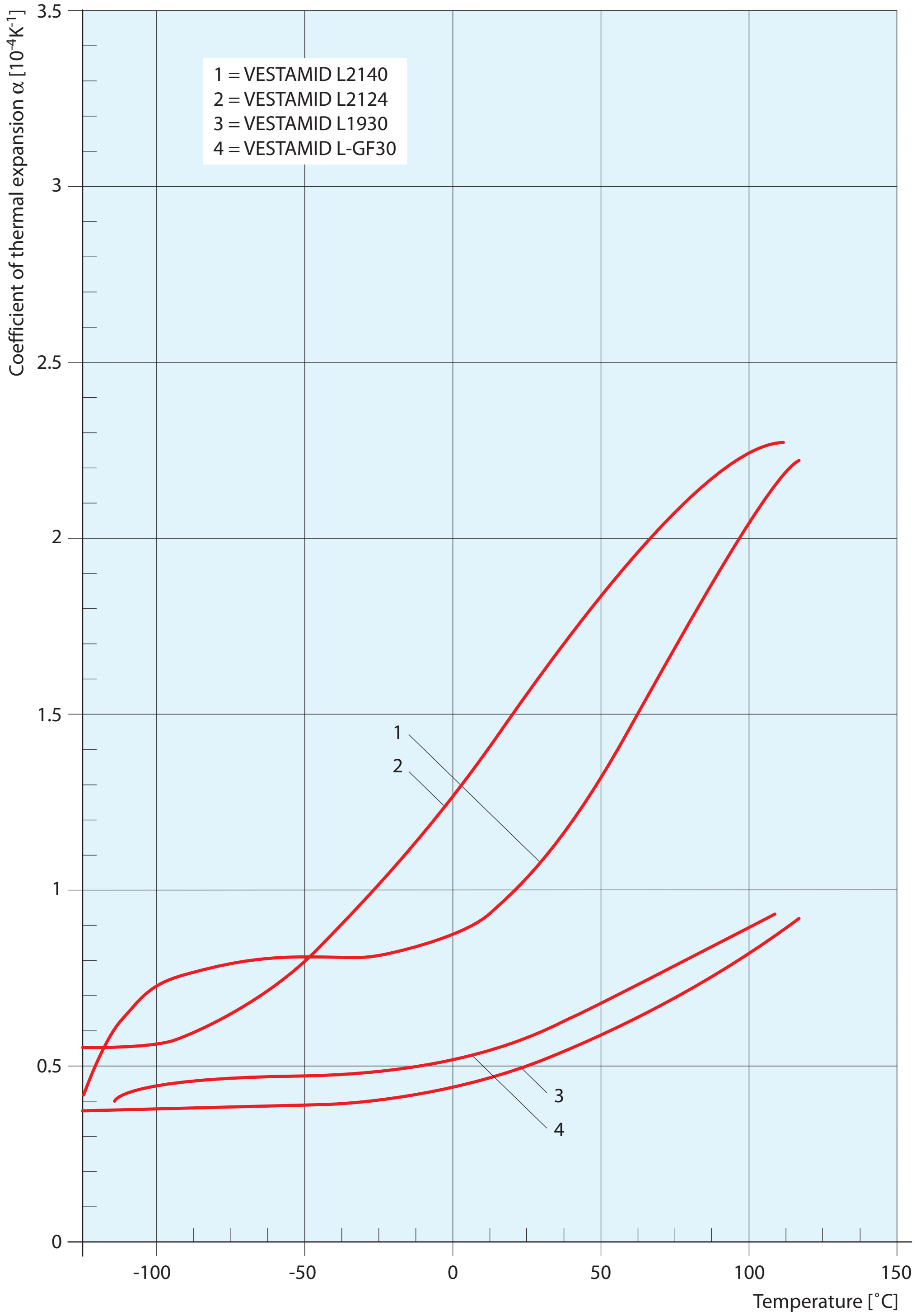


Figure 4: Coefficient of linear thermal expansion acc. to ISO 11359
Molded test specimens of 45 x 15 x 10 mm

1.2.4 Long-term properties of PA 12 under mechanical load

At high temperatures, creep occurs, especially in the case of non-reinforced thermoplastics subjected to stress. Although PA 12 performs relatively well under these conditions, the designer must take into consideration that under continuous load the long-term creep modulus is reduced compared with the short-term tensile modulus. On the other hand, this means that, under continuous strain, the resulting stress and force are reduced gradually.

Usually the creep resistance is determined with an uniaxial tensile creep test according to ISO 899, under different loads and temperatures. Figures 5–22 show the creep curves and creep modulus curves at room temperature, 60 and 100 °C, respectively, for some representative VESTAMID grades. By using the regression analysis method, the test results are linearized into creep curves. With these curves, it is possible to calculate the stress-strain curves, stress-time curves and creep modulus curves.

The incorporation of reinforcing fibers (glass or carbon fibers) reduces the creep in the orientation direction of the fibers, while the incorporation of plasticizers increases the tendency to creep. Thermoplastics containing volatile plasticizers will lose them gradually at higher temperatures. This leads to a contraction that is superimposed on the elongation caused by the applied stress.

If the creep curves are linear, with medium strains at corresponding stresses, it is normally possible to extrapolate the curves to about ten times the test duration, provided that no harsh environment (weathering, UV-light, hot air, hot water or chemicals) exists.
For many VESTAMID resins values up to 10,000 hours have been measured.

Details and data about the measurements can be requested from the Technical Marketing Department of High Performance Polymers.

VESTAMID L2140
Tensile creep test according to ISO 899

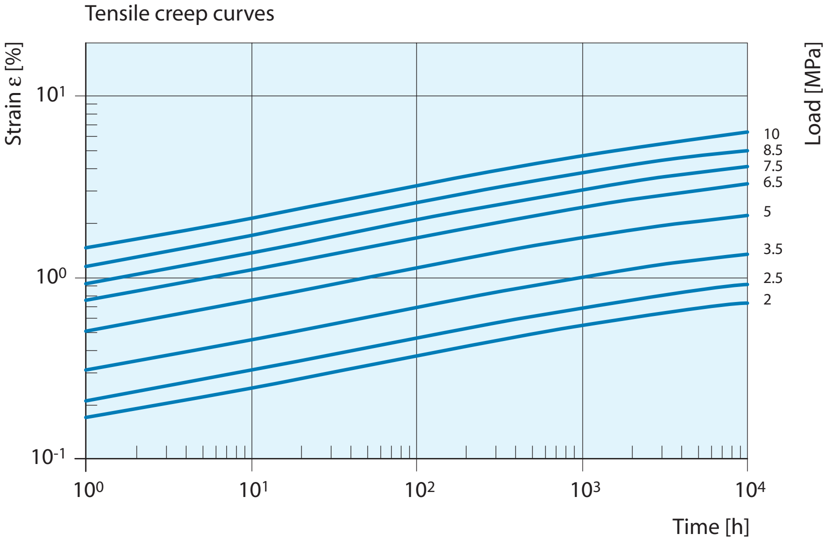


Figure 5:
Test climate 23 °C/50% r.h.

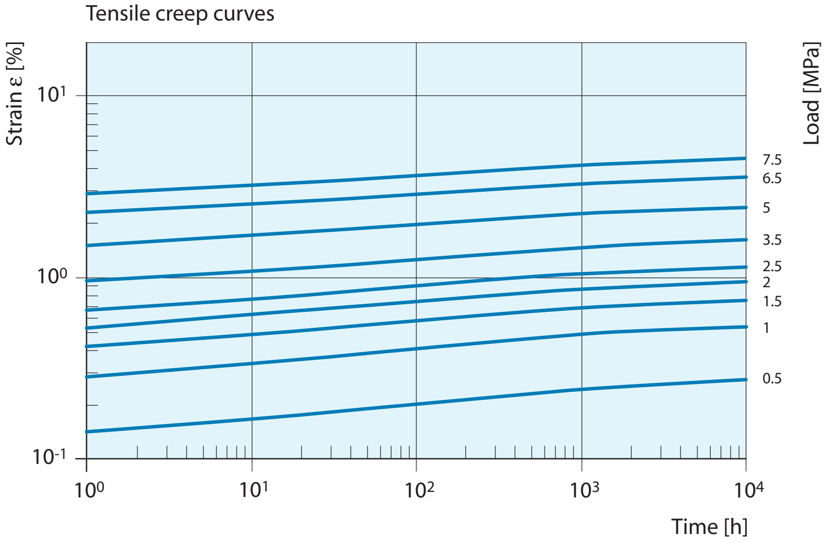


Figure 6:
Test climate 60 °C

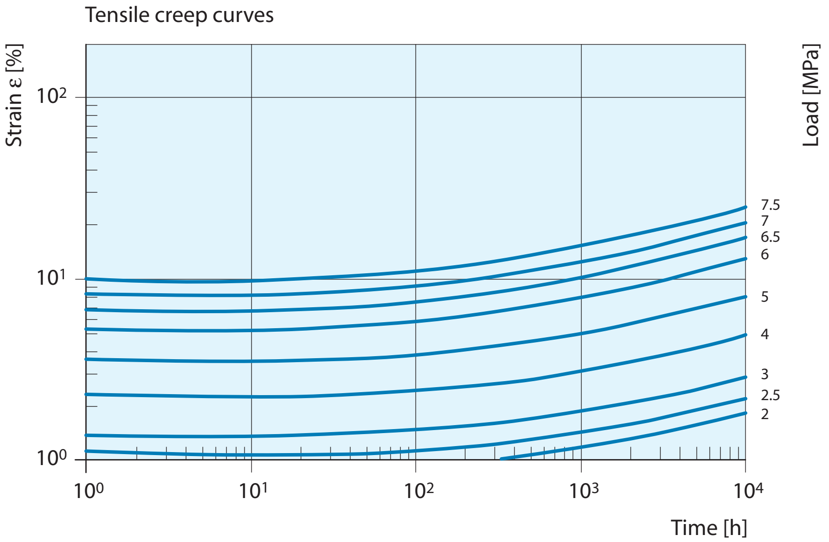


Figure 7:
Test climate 100 °C

VESTAMID L2140
Tensile creep test according to ISO 899

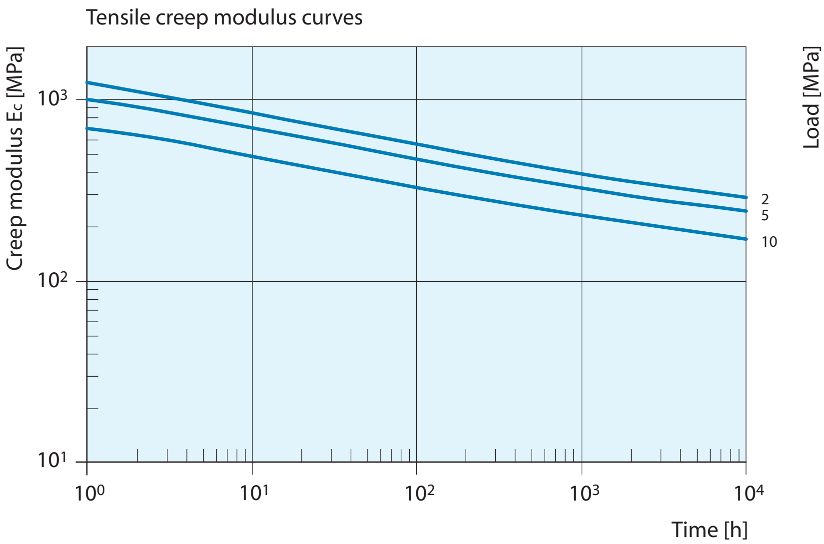


Figure 8:
Test climate 23 °C/50% r.h.

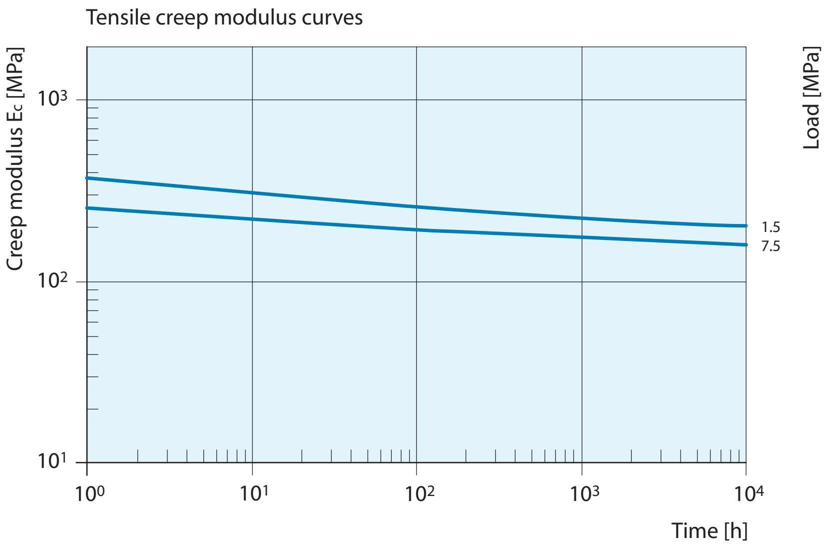


Figure 9:
Test climate 60 °C

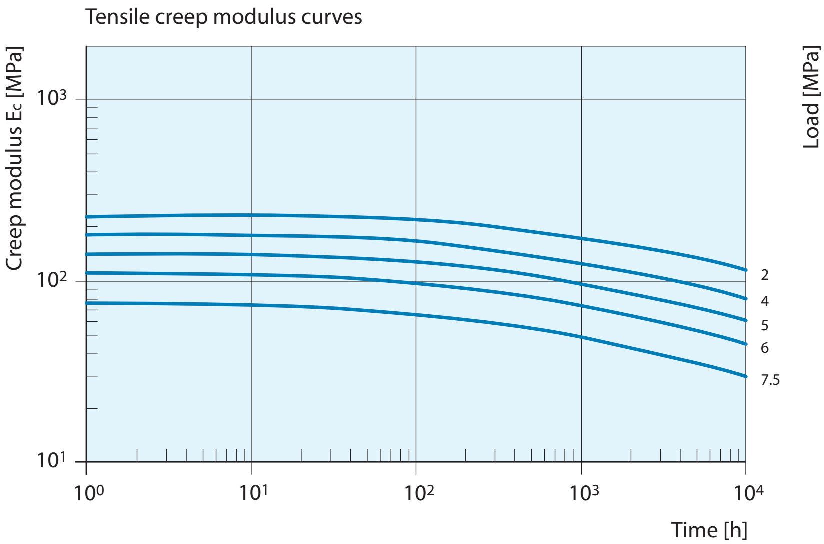


Figure 10:
Test climate 100 °C

VESTAMID L2124
Tensile creep test according to ISO 899

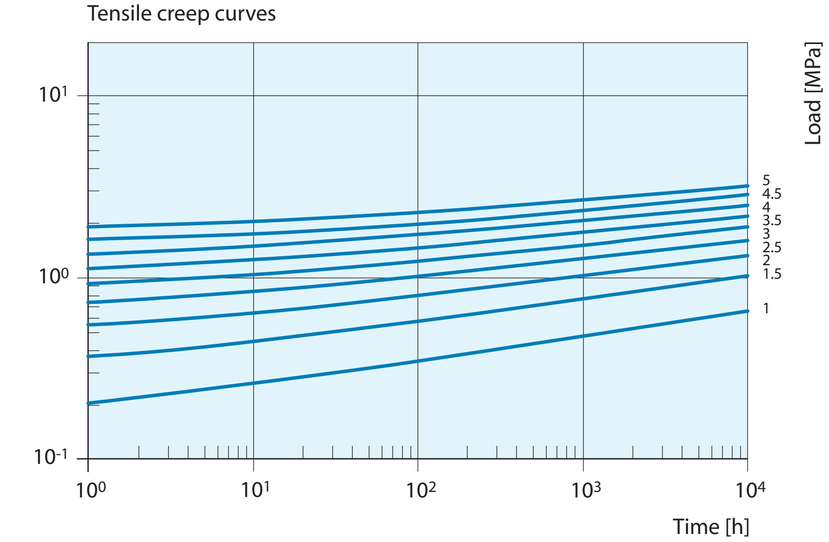


Figure 11:
Test climate 23 °C/50% r.h.

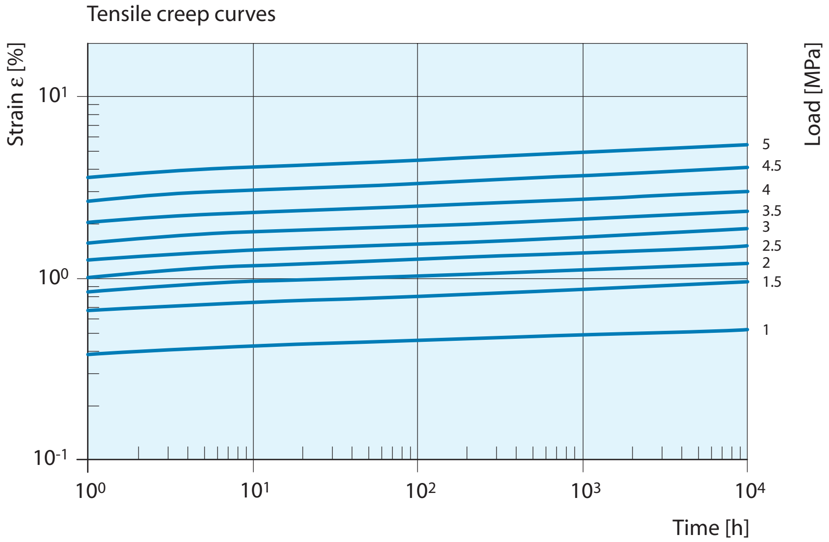


Figure 12:
Test climate 60 °C

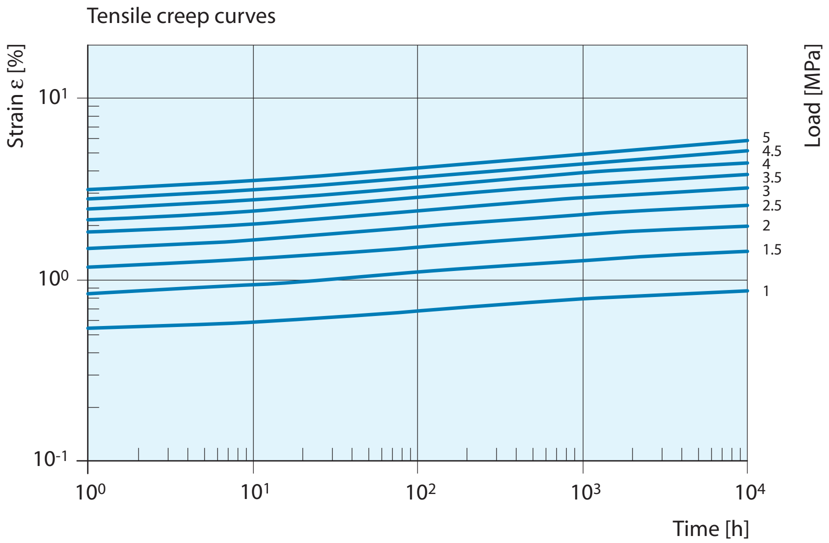


Figure 13:
Test climate 100 °C

VESTAMID L2124
Tensile creep test according to ISO 899

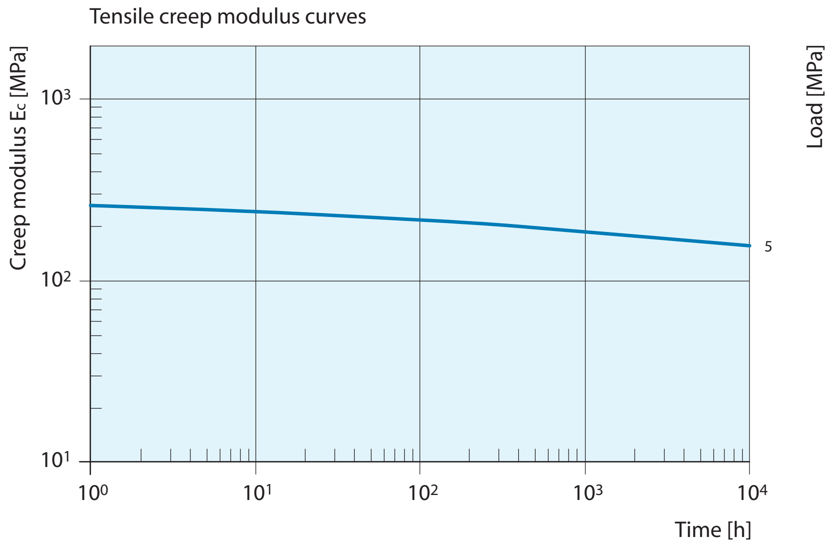


Figure 14:
Test climate 23 °C/50% r.h.

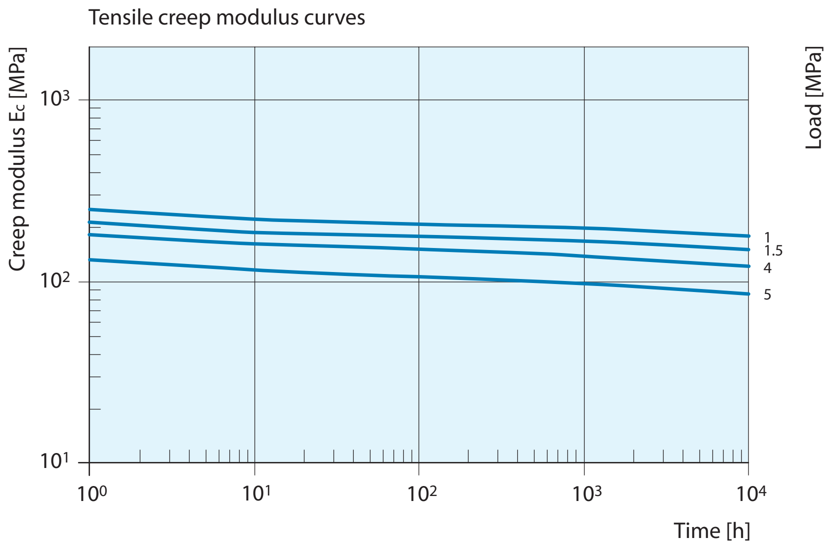


Figure 15:
Test climate 60 °C

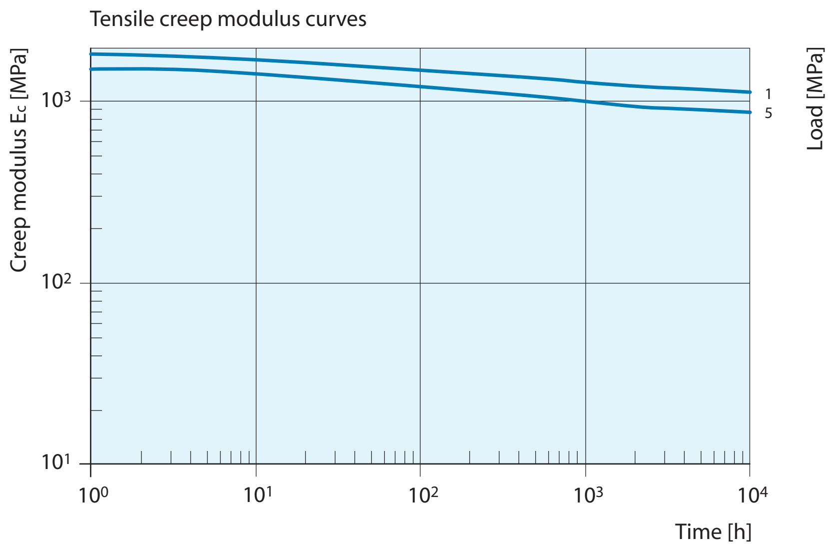


Figure 16:
Test climate 100 °C

VESTAMID L-GF30
Tensile creep test according to ISO 899

Tensile creep curves

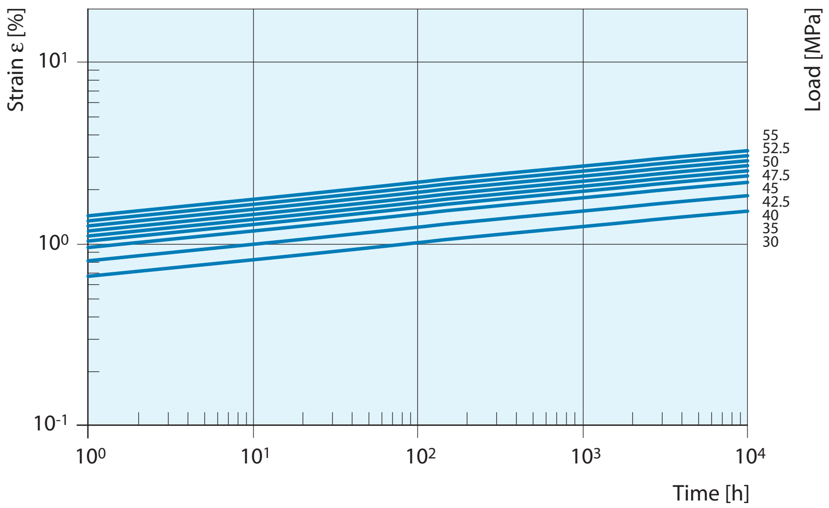


Figure 17:
Test climate 23 °C/50% r.h.

Tensile creep curves

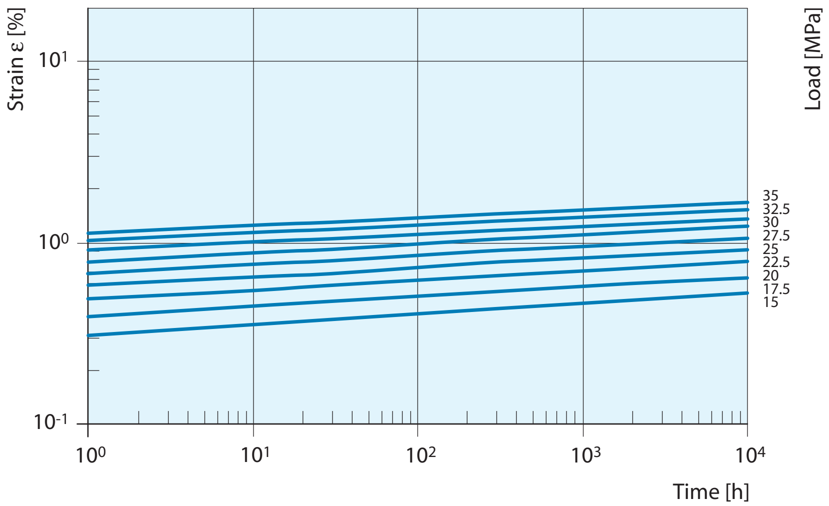


Figure 18:
Test climate 60 °C

Tensile creep curves

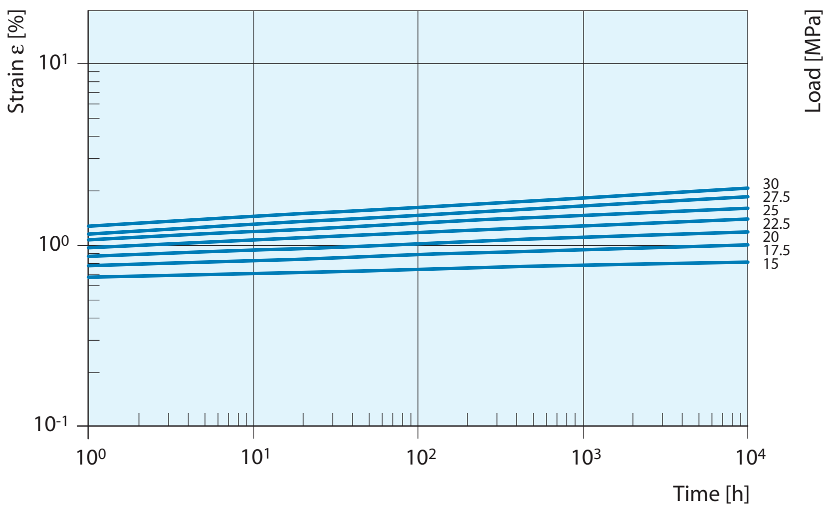


Figure 19:
Test climate 100 °C

VESTAMID L-GF30
Tensile creep test according to ISO 899

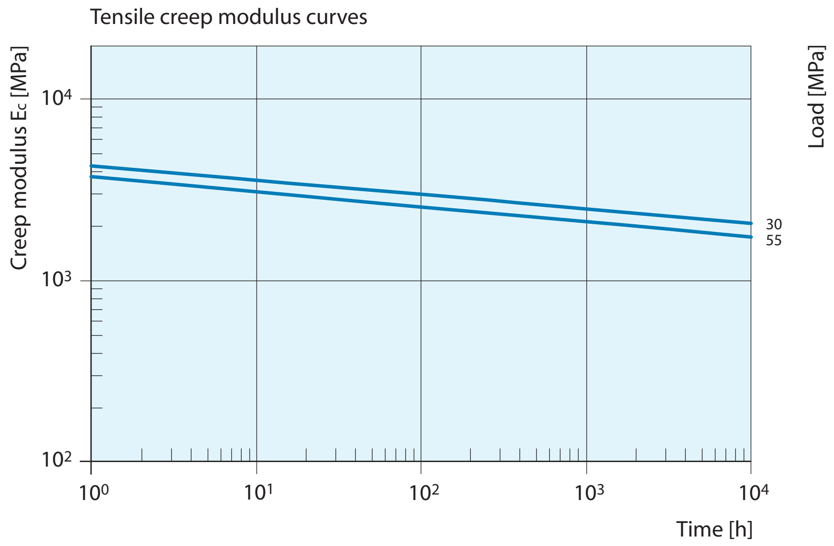


Figure 20:
Test climate 23 °C/50% r.h.

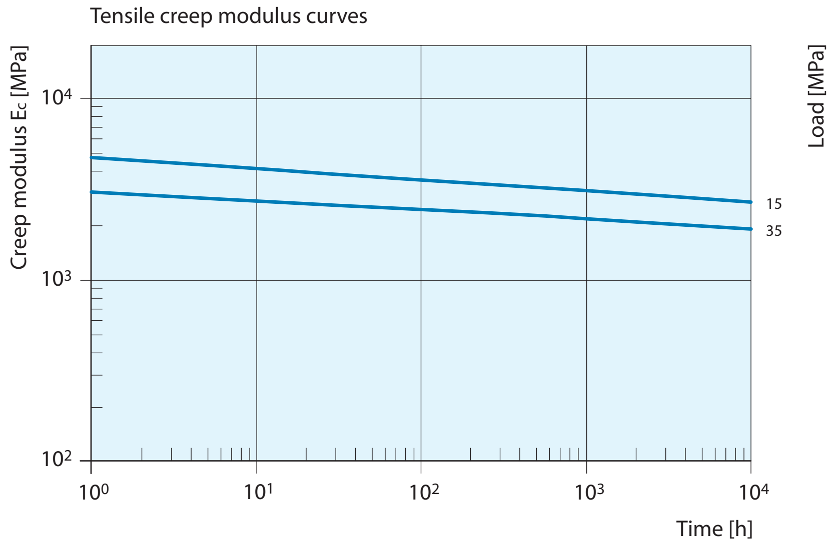


Figure 21:
Test climate 60 °C

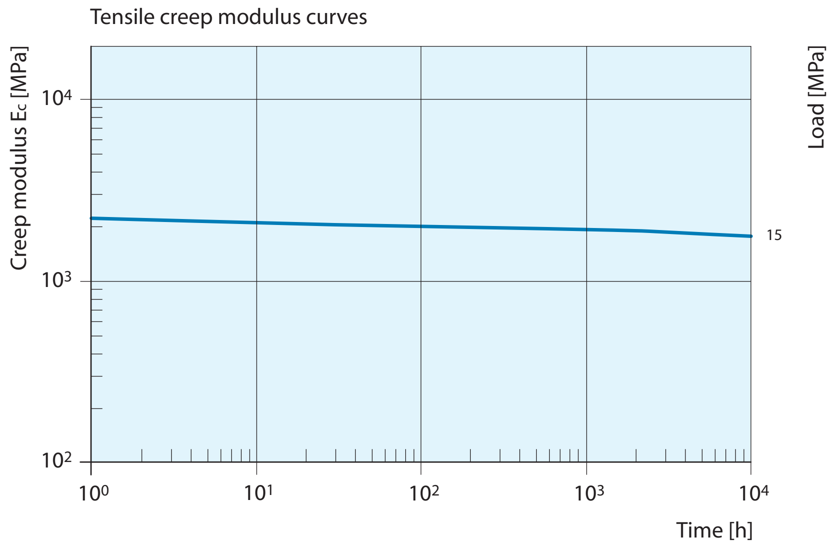


Figure 22:
Test climate 100 °C

1.2.5 Resistance of PA 12 against heat, radiation, and chemical attack

For thermoplastics to perform optimally over long periods within aggressive environments (UV radiation, hot air, etc.), it is necessary to incorporate the appropriate stabilizers.

Heat aging

Appropriate heat stabilizers improve the long-term performance of polyamides when used in air under higher temperatures. Except for some special products, all VESTAMID compounds are usually equipped with an optimized stabilization package. To give a comparative measure for the continuous temperature loading that a plastic can withstand, it is subjected to a heat aging test according to IEC 216 at several temperature steps. The moment at which a critical property falls to a defined limit (usually to 50% of its initial value) is then determined. The corresponding time-temperature combinations obtained with these methods are extrapolated to 20,000 hours (or another period) to produce the temperature index TI (see Figure 23).

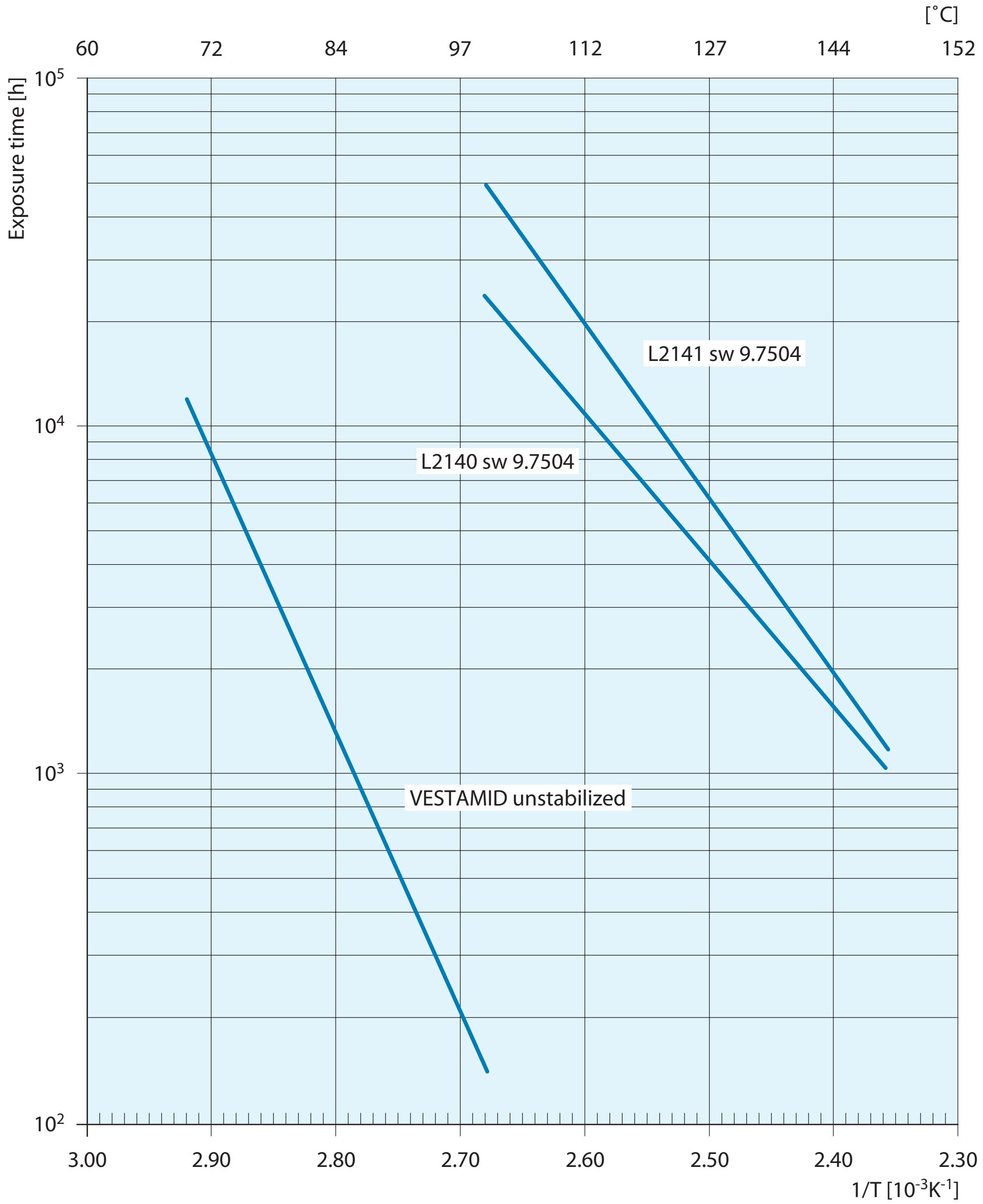
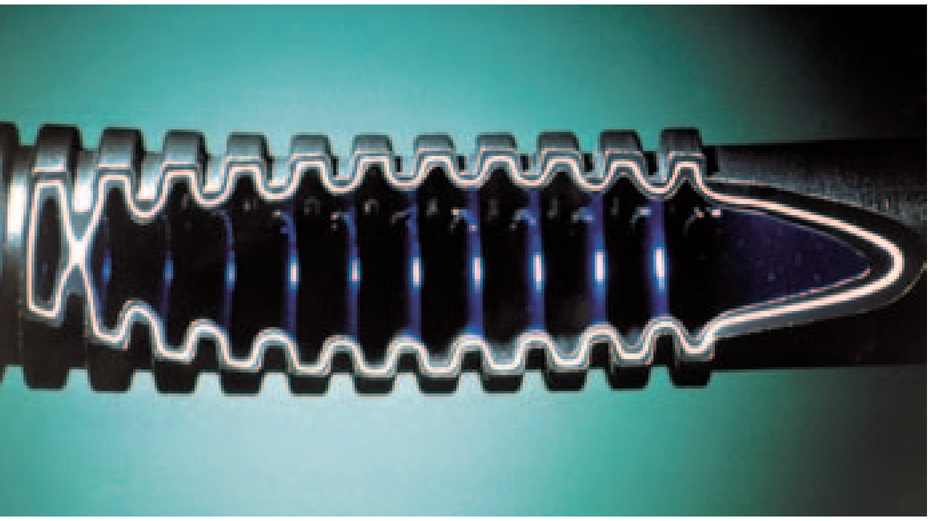


Figure 23: Temperature-time limits acc. to IEC 216; sw = black
Criterion: Drop of strain at break to 50% (tensile test acc. to ISO 527)

Moreover, a number of VESTAMID compounds are UL-listed according to UL746 B for the relative temperature index (RTI). The latter represents the long-term performance over approximately 60,000 hours. Details can be found in the specific product information "Underwriters Laboratories (UL) listings for thermoplastic resins by Degussa AG". Specific queries about chemical resistance at higher temperatures can be addressed to the Technical Marketing Department of High Performance Polymers.



U.V. resistance

Exposure to short-wave light of wavelengths less than 400 nm causes an accelerated decrease in molecular mass, leading to the embrittlement of moldings or semi-finished products. This deterioration can be reduced substantially by adding light stabilizers. UV absorbers and/or radical scavengers improve weathering performance remarkably. The best protection against irradiation, however, is obtained by the use of suitable grades of carbon black if blackening can be done. Although light stabilizers and UV stabilizers improve weathering resistance substantially, they are not as effective as carbon black. The addition of colorants can have either a stabilizing or sensitizing effect. Additionally, mechanical properties can be affected by carbon black or pigments.

Accelerated testing is carried out in weathering cabinets, with or without simulated rain. The spectrum of the UV radiation used corresponds to a large extent to that of sunlight. The reduction in strain at break or the notched impact strength is used as the preferred test criterion.

Hydrolysis resistance

Polycondensation products, to which polyamides also belong, have a limited resistance against hot water or moist air at higher temperatures. However, compared with other polyamides, PA 12 exhibits good hydrolysis resistance. PA 12 is gradually degraded by hot water. Compounds with a higher molecular mass will last longer than grades with a lower molecular mass. Hydrolysis occurs more rapidly in acid media than in neutral or alkaline ones (refer also to Section "Chemical resistance"). Up to temperatures of 70 to 80 °C standard grades can be regarded as practically stable against pure water attack.

Resistance against ionizing radiation
PA 12 has a high resistance to ionizing radiation. For example, films manufactured from VESTAMID L1901 (0.03 to 0.1 mm thick) were exposed to irradiation dosages of 25 kilo Gray (= 2.5 Mrad), 50 kGy and 100 kGy. It was not until the dosage reached 100 kGy that a decided reduction in strain at break occurred and a slight greying was observed.

Thicker test specimens made of VESTAMID L1940 were irradiated with electron beam doses of 400 kGy without any noticeable changes in the mechanical properties.

The crosslinking of PA 12 can be carried out only by addition of a reactive crosslinking agent. In addition to a small increase in the tensile strength, the crosslinking results in a considerable increase in the heat deflection temperature extending beyond the melting point of the crystalline fraction.

Chemical resistance

In the interaction between polymers and the chemicals, one can distinguish between the following cases:

- The chemical will be absorbed to a certain amount by the polymer and this causes the plastic article to swell, to a greater or lesser extent. This swelling is reversible for the most part. That is, if the acting media have been removed, the molded part will regain its original form, provided that the chemical has not extracted soluble additives. Swelling has a plasticizing effect and reduces tensile strength while increasing flexibility and impact resistance.
- The chemical frequently acts as a solvent only at higher temperatures whereas at lower temperatures it is only a powerful swelling agent.
- The chemical causes the polymer to degrade, the speed of which is highly temperature-dependent.

PA 12 is highly resistant against chemically induced stress cracking. These cases can therefore be neglected here.

In order to present not only the qualitative effect of numerous chemicals, but also to be able to give more exact information about the chemical resistance, we concentrated on using a selection of representatives of typical chemical groups and their effect on rigid PA 12 and plasticized PA 12. Please refer to Table 7 for details.

The chemical resistance of filled and reinforced VESTAMID compounds corresponds to that of rigid PA 12 with the difference that the swelling and consequent changes in properties are reduced in line with the content of additives.

Table 7: Chemical resistance of VESTAMID L2140 and 2124

Test medium	Test temperature [°C]	Duration [h]	VESTAMID L2140 Weight change[1] [%]	VESTAMID L2140 Tensile modulus[2] [MPa]	VESTAMID L2140 CHARPY notched impact strength[3] [kJ/m²]	VESTAMID L2124 Weight change[1] [%]	VESTAMID L2124 Tensile modulus[2] [MPa]	VESTAMID L2124 CHARPY notched impact strength[3] [kJ/m²]
Control specimen	–	–	–	1440	18	–	570	n.b.
Sulphuric acid, 1/2 mol/l	23	1170	+ 0.9	1130	n.b.	+ 0.9	530	n.b.
	90	331	+ 1.7	830	4.3	+ 1.6	520	7.5
Battery acid, 30%	23	1556	+ 1.0	1360	34; 5/10 n.b.	+ 1.0	570	n.b.
	90	42	+ 3.0	870	9.3	+ 3.5	390	13
Hydrochloric acid, 1 mol/l	23	226	+ 0.5	870	n.b.	+ 0.5	540	n.b.
	90	226	+ 1.7	840	3.6	+ 1.4	580	3.6
Nitric acid, 1 mol/l	23	1624	+ 1.6	1060	n.b.	+ 0.6	520	n.b.
	90	21	+ 2.2	900	4.4	+ 1.5	510	10.7
Formic acid, 85%	23	761	+26.0	370	n.b.	+15.4	280	n.b.
	90	24	decomp.	–	–	decomp.	–	–
Acetic acid, 2 mol/l	23	1554	+ 1.9	960	n.b.	+ 2.1	470	n.b.
	90	330	+ 4.5	850	1.7	+ 3.6	600	6.8
Sodium hydroxide 1 mol/l	23	1293	+ 0.9	1100	n.b.	+ 0.1	530	n.b.
	90	330	+ 1.3	860	n.b.	+ 3.2	640	18
Chlorine water, 16%	23	1651	+ 0.8	1350	70	+ 1.1	580	n.b.
Aqueous ammonia, 25%	23	1195	+ 1.1	1370	n.b.	+ 0.5	520	n.b.
Hexane	23	1200	+ 0.4	1380	36	+ 0.5	530	n.b.
	68	264	+ 1.1	1130	40	+ 0.4	460	n.b.
Toluene and benzene	23	1672	+ 5.9	910	n.b.	+ 3.2	530	n.b.
	70	330	+10.3	630	n.b.	+ 2.2	480	n.b.
Premium fuel	23	1552	+ 2.1	1160	n.b.	+ 3.9	580	n.b.
	67	432	+ 7.5	640	n.b.	– 0.1	460	n.b.
ASTM fuel B	23	1606	+ 1.9	1180	43	+ 2.9	500	n.b.
	70	331	+ 5.7	710	n.b.	+ 0.6	520	n.b.
ASTM fuel B + ethanol (80:20 vol%)	23	1672	+14.2	550	n.b.	+ 4.7	440	n.b.
	70	332	+16.7	400	n.b.	+ 6.0	370	n.b.
Methanol	23	1313	+ 9.7	530	n.b.	+ 0.6	420	n.b.
	64	357	+11.9	470	n.b.	+ 1.3	400	n.b.
Isoamyl alcohol	23	1552	+ 2.9	1100	35	+ 3.8	490	n.b.
	70	330	+15.9	450	n.b.	+ 5.8	370	n.b.
Methyl ethyl ketone	23	1581	+ 2.3	960	n.b.	– 1.7	580	n.b.
	68	300	+ 5.1	420	n.b.	– 1.5	500	n.b.
Trichloroethylene	23	1530	+20.3	560	n.b.	+14.7	430	n.b.
	66	309	+21.6	510	n.b.	+14.4	390	n.b.
Butyl acetate	23	1553	+ 1.0	1360	23; 6/10 n.b.	0	530	n.b.
	68	300	+ 4.4	570	n.b.	– 2.5	430	n.b.
PYDRAUL® 150[4]	23	1528	+ 0.5	1800	27; 5/10 n.b.	+ 0.5	580	n.b.
	90	352	+ 2.2	1320	16	– 1.5	680	17
SKYDROL® HT[4]	23	1506	+ 0.2	1640	6.0	+ 0.1	590	n.b.
	90	331	+ 3.5	940	5/10 n.b.	+ 0.8	520	n.b.
STOP® HD[4]	23	1581	+ 0.7	1480	32; 5/10 n.b.	+ 1.3	520	n.b.
	90	330	+10.6	500	n.b.	+ 1.4	440	n.b.
GIRLING®[4]	23	1552	0	1630	32; 4/10 n.b.	0	530	n.b.
	90	352	+ 4.9	690	n.b.	– 3.1	530	n.b.
LOCKHEED®[4]	23	1623	0	1660	25	+ 0.2	570	n.b.
	90	448	+ 5.1	640	n.b.	+ 1.7	550	n.b.

1) Maximum value during tests. Differences between rigid and plasticized PA 12 are mainly caused by partial plasticizer extraction
2) acc. to ISO 527-1/-2
3) n.b. = no break; 34; 5/10 = 5 of 10 bars not broken, average impact energy of broken bars 34 kJ/m²
4) Hydraulic fluid

1.2.6 Abrasion and frictional properties

Polyamides are characterized by a very high abrasion resistance. This can be determined according to DIN 53754 (Taber) or DIN 53516. The test is done by abrasion with emery paper. Harder compounds have a higher abrasion than softer materials. The abrasion increases again only in the case of very soft compounds. The following table shows some values.

Table 8: Abrasion of VESTAMID compounds

VESTAMID	Abrasion according to	
	DIN 53754 (mg)	DIN 53516 [mm^3]
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 specimens conditioned at 23 °C, 50 % relative humidity. Emery paper was changed after every 100 revolutions.

For bearings or sliding parts the abrasion is of less importance than the coefficient of sliding friction. The coefficient depends on the bearing load, rotational speed, surface structure, or hardness of the mating surface, and the temperature.

The evaluations were conducted using a slide bearings test apparatus, with the results as shown in Figures 24–26. For small to medium loads VESTAMID shows good results. However, it is important to test different mating surfaces against each other. The coefficient of friction of polyamide against metal is lower than of metal against metal.

The tests were carried out using hardened steel shafts at low roughness (2 µm peak to valley height). The incorporation of reinforcements or fillers (glass fibers, graphite) has very little influence on the slide friction and wear for as long as the surface skin of the molded part remains undamaged. It is only when the additives come to the surface that their influence becomes apparent, e.g., for glass fibers, higher abrasion of the mating surface takes place.

Whenever the application of lubricants may cause problems, PA 12 should be the first choice for the manufacture of bearings. Nevertheless, it should be mentioned that the optimum solution is offered by the use of bearings which were lubricated in assembly (maintenance free bearings). The high chemical resistance of PA 12 allows the use of practically all lubricants. As a result of lubrication, the coefficient of friction is considerably reduced and wear is practically eliminated.

On a final note, we would like to point out one special advantage that VESTAMID L2101 has at very low temperatures. Under cryogenic conditions, it serves excellently as shot granules for deburring rubber parts.

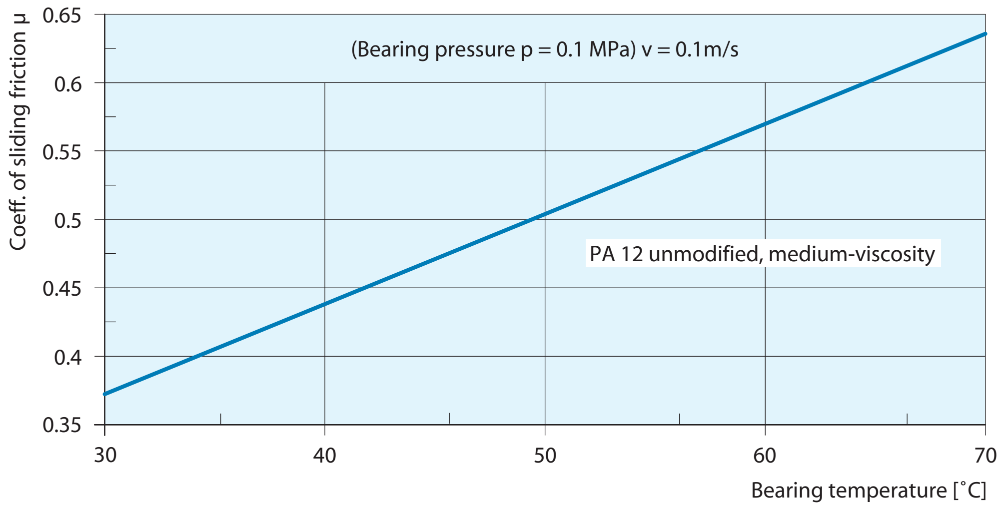


Figure 24: Coefficient of sliding friction as function of bearing temperature at mean pressure load. (Lubrimeter test acc. to A. Bartel).

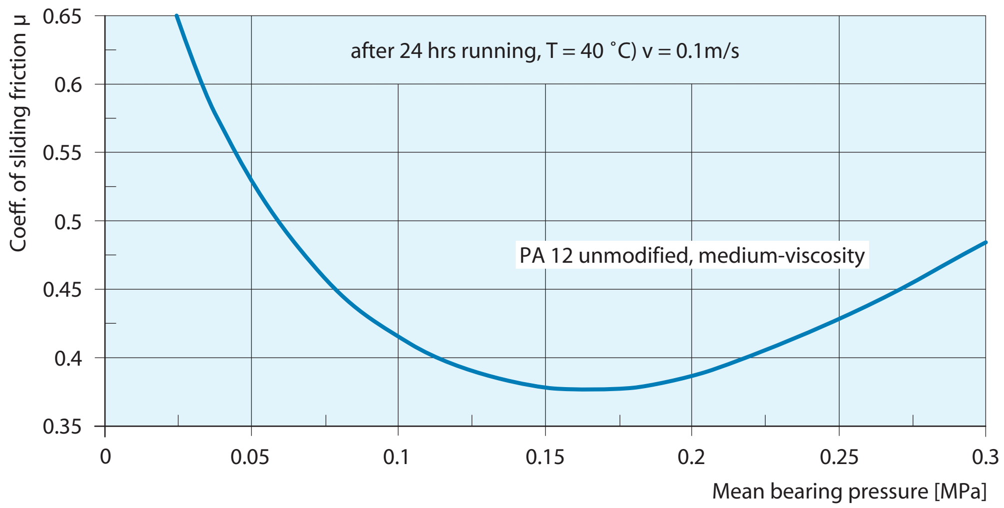


Figure 25: Coefficient of sliding friction as function of pressure load. (Lubrimeter test acc. to A. Bartel).

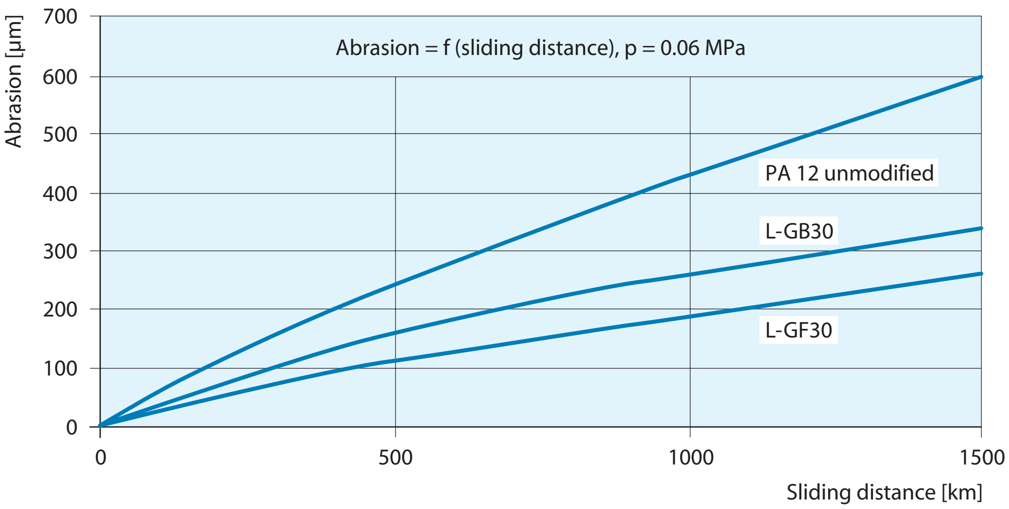


Figure 26: Abrasion on bearing as function of the sliding distance, and PA 12 modification

Tables

2 Comparative Tables of Grades

2.1 Unfilled PA 12 compounds

2.1.1 Physical, thermal, mechanical properties and flammability

Property		Test method		Unit	L1670
Density	23 °C	ISO 1183		g/cm³	1.01
Melting temperature		ISO 3146, ISO 11357	Peak temperature 2. heating	°C	178
Temperature of deflection under load		ISO 75	Method A 1.8 MPa	°C	50
			Method B 0.45 MPa	°C	120
Vicat softening temperature		ISO 306	Method A 10N	°C	170
			Method B 50N	°C	140
Linear thermal expansion		ISO 11359	23-55 °C, determined on specimen 45·15·10 mm	$10^{-4} \cdot K^{-1}$	1.5
Flammability acc. UL 94		IEC 60695	1.6 mm		HB
			3.2 mm		HB
Water absorption		ISO 62	23 °C, saturation[2)]	%	1.4
		determined on 1 mm thick sheets	23 °C/50% rel. humid.	%	0.7
Mold shrinkage		ISO 294-4	in flow direction	%	0.9
		processing cond. acc. to ISO 1874-2	in transverse direction	%	1.1
Tensile test	Stress at yield	ISO 527-1/2		MPa	46
	Strain at yield			%	6
	Stress at break			MPa	–
	Strain at break			%	>50
Tensile modulus		ISO 527-1/2		MPa	1400
CHARPY impact strength[3)]		ISO 179/1eU	23 °C	kJ/m²	N
			-30 °C	kJ/m²	N
CHARPY notched impact strength[3)]		ISO 179/1eA	23 °C	kJ/m²	4 C
			-30 °C	kJ/m²	5 C

2.1.2 Electrical properties

Property	Test method		Unit	L1670
Relative permittivity	IEC 60250	23 °C / 100 Hz	–	3.8
		23 °C / 1 MHz	–	2.2
Dissipation factor	IEC 60250	23 °C / 100 Hz	10^{-4}	450
		23 °C / 1 MHz	10^{-4}	280
Electric strength	IEC 60243-1	K20 / P50	kV/mm	27
Comparative tracking index	IEC 60112	Test solution A 50 drops value	–	> 600
CTI		100 drops value	–	600
Volume resistivity	IEC 60093		Ω·cm	10^{15}
Electrolytic corrosion	IEC 60426		Step	A1

1) sw = black
2) Platicized compounds were not stored in water because of slight plasticizer migration.
3) N = no break, P = partial break, C = complete break

L1940	X7373	L2101F	L2106F	L2140 L2170 LX9007	L2141sw 1)	LX9008
1.01	1.01	1.01	1.01	1.01	1.01	1.01
178	178	178	175	178	178	176
50	50	50	40	50	50	50
110	130	110	80	110	110	110
170	175	170	170	170	170	170
140	150	140	130	140	140	135
1.5	1.5	1.5	1.5	1.4	1.5	1.5
HB	HB	HB	HB	HB	HB	HB
HB	HB	HB	HB	HB	HB	HB
1.5	1.5	1.6	1.8	1.6	1.5	1.6
0.8	0.7	0.8	0.8	0.7	0.7	0.7
0.85	0.95	0.7	0.7	0.65	0.7	–
1.15	1.15	1.25	1.2	1.25	1.3	–
45	47	45	45	47	46	42
5	5	5	5	5	5	5
–	–	–	–	–	–	50
>50	>50	> 50	> 50	> 50	> 50	> 150
1350	1500	1400	1300	1400	1500	1450
N	N	N	N	N	N	N
N	N	N	N	N	N	N
6 C	6 C	32 C	7 C	16 C	10 C	45 P (C)
6 C	6 C	9 C	7 C	9 C	8 C	20 C

L1940	X7373	L2101F	L2106F	L2140 L2170 LX9007	L2141sw 1)	LX9008
3.8	4.2	3.7	3.7	3.7	9.7	3.7
2.5	3.8	3.0	3.0	3.0	4.0	3.0
450	750	450	450	450	2100	450
310	520	280	280	260	1100	260
27	30	29	27	26	35	26
> 600	>600	> 600	> 600	> 600	> 600	> 600
600	600	600	600	600	600	600
10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{12}	10^{15}
A1	A1	A1	A1	A1	A1	A1

2.2 Plasticized PA 12 compounds

2.2.1 Physical, thermal, mechanical properties and flammability

Property		Test method		Unit	L1723	L2121
Density	23 °C	ISO 1183		g/cm^3	1.03	1.02
Melting temperature		ISO 3146, ISO 11357	Peak temperature 2. heating	°C	173	176
Temperature of defection under load		ISO 75	Method A 1.8 MPa	°C	45	45
			Method B 0.45 MPa	°C	95	110
Vicat softening temperature		ISO 306	Method A 10N	°C	165	170
			Method B 50N	°C	130	130
Linear thermal expansion		ISO 11359	23-55 °C, determined on specimen 45·15·10 mm	$10^{-4}\cdot K^{-1}$	1.8	1.6
Flammability acc. UL94		IEC 60695	1.6 mm		HB	HB
			3.2 mm		HB	HB
Water absorption		ISO 62	23 °C, saturation[2)]	%	–	–
		determined on 1 mm thick sheets	23 °C/50% rel. humid.	%	0.5	0.6
Mold shrinkage		ISO 294-4	in flow direction	%	1.65	0.6
		processing cond. acc. to ISO 1874-2	in transverse direction	%	1.5	1.65
Tensile test	Stress at yield	ISO 527-1/2		MPa	30	35
	Strain at yield			%	27	20
	Stress at break			MPa	–	–
	Strain at break			%	> 50	> 50
Tensile modulus		ISO 527-1/2		MPa	480	700
CHARPY impact strength [3)]		ISO 179/1eU	23 °C	kJ/m^2	N	N
			-30 °C	kJ/m^2	N	N
CHARPY notched impact strength [3)]		ISO 179/1eA	23 °C	kJ/m^2	24 C	40 C
			-30 °C	kJ/m^2	5 C	7 C

2.2.2 Electrical properties

Property	Test method		Unit	L1723	L2121
Relative permittivity	IEC 60250	23 °C / 100 Hz	–	10	6.5
		23 °C / 1 MHz	–	3.7	3.4
Dissipation factor	IEC 60250	23 °C / 100 Hz	10^{-4}	1600	1900
		23 °C / 1 MHz	10^{-4}	1200	550
Electric strength	IEC 60243-1	K20 / P50	kV/mm	33	34
Comparative tracking index	IEC 60112	Test solution A 50 drops value	–	> 600	> 600
CTI		100 drops value	–	600	600
Volume resistivity	IEC 60093		Ω·cm	10^{12}	10^{14}
Electrolytic corrosion	IEC 60426		Step	A1	A1

1) sw = black
2) Platicized compounds were not stored in water because of slight plasticizer migration.
3) N = no break, P = partial break, C = complete break

L2122	X7393	L2124	L2123	X7293	LX9013	L2128
1.03	1.02	1.03	1.03	1.02	1.02	1.05
173	173	171	171	172	172	164
45	45	45	45	45	45	40
95	115	90	80	100	100	70
165	170	165	165	165	165	145
125	130	125	120	130	130	100
1.7	1.4	1.8	1.8	1.8	1.8	1.8
HB	HB	HB	HB	HB	HB	HB
HB	HB	HB	HB	HB	HB	HB
–	–	–	–	–	–	–
0.5	0.6	0.5	0.6	0.5	0.6	0.5
0.6	0.8	0.7	0.65	0.65	0.65	0.65
1.6	1.35	1.55	1.4	1.35	1.35	1.2
30	31	26	24	27	–	18
26	28	31	32	32	–	45
–	47	–	–	–	43	–
> 50	> 150	> 50	> 50	>50	> 150	> 50
490	570	400	370	400	400	230
N	N	N	N	N	N	N
N	N	N	N	N	N	N
68 P	115 P	150 P	115 P	130 P	140 P	N
6 C	8 C	6 C	13 C	7 C	7 C	6 C

L2122	X7393	L2124	L2123	X7293	LX9013	L2128
10	7	12	10	11	11	17
3.3	4.2	3.8	3.6	4.6	4.6	3.8
1900	1900	1600	2000	2000	2000	3000
1000	1100	1500	1100	1900	1900	2400
32	27	31	29	30	30	31
> 600	> 600	> 600	> 600	> 600	> 600	> 600
600	600	600	600	600	600	600
10^{13}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{10}
A1	–	A1	A1	–	–	A1

2.3 Filled, reinforced and flame retardant containing PA 12 compounds

2.3.1 Physical, thermal, mechanical properties and flammability

Property		Test method		Unit	L-GF15	L1833
Density	23 °C	ISO 1183		g/cm³	1.12	1.17
Melting temperature		ISO 3146, ISO 11357	Peak temperature 2. heating	°C	178	178
Temperature of defection under load		ISO 75	Method A 1.8 MPa	°C	160	160
			Method B 0.45 MPa	°C	175	175
Vicat softening temperature		ISO 306	Method A 10N	°C	175	175
			Method B 50N	°C	170	175
Linear thermal expansion		ISO 11359	23-55 °C; determined on specimen 45·15·10 mm	$10^{-4}\cdot K^{-1}$	0.8	0.7
Flammability		IEC 60695	1.6 mm		HB	HB
acc. UL94			3.2 mm		V-2	V-2
Water absorption		ISO 62	23 °C, saturation	%	1.3	1.2
		determined on 1 mm thick sheets	23 °C, 50% rel. humid.	%	0.6	0.6
Mold shrinkage		ISO 294-4	in flow direction	%	0.35	0.2
		processing cond. acc. to ISO 1874-2	in transverse direction	%	0.65	0.65
Tensile test	Stress at yield	ISO 527-1/2		MPa	–	–
	Strain at yield			%	–	–
	Stress at break			MPa	95	105
	Strain at break			%	6	6
Tensile modulus		ISO 527-1/2		MPa	3900	5000
CHARPY impact strength 2)		ISO 179/1eU	23 °C	kJ/m²	75 C	90 C
			-30 °C	kJ/m²	80 C	95 C
CHARPY notched impact strength 2)		ISO 179/1eA	23 °C	kJ/m²	17 C	25 C
			-30 °C	kJ/m²	11 C	16 C

2.3.2 Electrical properties

Property	Test method		Unit	L-GF15	L1833
Relative permittivity	IEC 60250	23 °C / 100 Hz	–	4.0	4.1
		23 °C / 1 MHz	–	3.4	3.4
Dissipation factor	IEC 60250	23 °C / 100 Hz	10^{-4}	380	370
		23 °C / 1 MHz	10^{-4}	260	260
Electric strength	IEC 60243-1	K20 / P50	kV/mm	44	41
Comparative tracking index	IEC 60112	Test solution A 50 drops value	–	> 600	> 600
CTI		100 drops value	–	600	600
Volume resistivity	IEC 60093		Ω·cm	10^{15}	10^{15}
Electrolytic corrosion	IEC 60426		Step	A1	A1

1) sw = black
2) N = no break, P = partial break, C = complete break
* determined on specimen 127·12.7·3.2 mm
** Development product, preliminary data

LX9105 **	L-GF30	LX9111	L1930	L-GB30	L-CF15 sw 1)	X7166	X7167	X7229
1.18	1.24	1.24	1.24	1.25	1.08	1.06	1.05	1.06
178	178	177	178	178	178	178	178	175
161	165	167	130	55	170	50	50	40
176	175	177	170	150	175	140	130	130
177	175	175	175	175	175	175	175	170
173	175	175	170	155	175	150	150	150
0.7	0.6	0.6	0.5	1.3	1.5	–	–	0.8
HB	HB	HB	HB	HB	HB	V-0	V-2	V-2
HB	HB	HB	HB	HB	HB	V-0	V-2	V-2
1.2	1.1	1.1	1.1	1.1	1.3	1.3	1.5	1.5
0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6
0.38	0.15	0.22	0.7	1.2*	0.15	0.65	0.6	0.55
0.62	0.65	0.62	0.6	1.2*	0.4	0.75	0.95	0.8
101	–	113	69	47	–	47	48	36
4.8	–	5	4	5	–	5	5	17
100	120	112	60	38	120	–	–	–
6.5	5	6	10	37	5	>50	>50	>50
5300	6500	6500	4000	2000	8000	1800	1700	1000
92 C	100 C	85 C	80 C	160 C	70 C	80 C	N	N
96 C	100 C	84 C	65 C	160 C	70 C	80 C	N	N
24 C	23 C	24 C	10 C	6 C	14 C	3 C	9 C	11 C
15 C	21 C	17 C	11 C	6 C	13 C	5 C	6 C	5 C

LX9105 **	L-GF30	LX9111	L1930	L-GB30	L-CF15 sw 1)	X7166	X7167	X7229
4.1	4.1	4.1	4.1	4.1	–	–	–	–
3.4	3.4	3.4	3.4	3.5	–	3.6	3.6	5
370	310	310	310	310	–	–	–	–
260	330	330	240	230	–	340	380	1700
41	44	44	40	31	–	28	28	27
> 600	> 600	> 600	> 600	> 600	100	> 600	> 600	> 600
600	600	600	600	600	–	600	600	600
10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	–	10^{14}	10^{14}	10^{13}
A1	A1	A1	A1	A1	A1	A1	A1	–

2.4 Permanently antistatic and electrically conductive PA 12 compounds [1]

2.4.1 Physical, thermal, mechanical properties and flammability

Property		Test method		Unit	L-R1-MHI sw[2]	L-R3-MHI sw[2]
Density	23 °C	ISO 1183		g/cm^3	1.11	1.10
Melting temperature		ISO 3146, ISO 11357	Peak temperature 2. heating	°C	178	178
Temperature of defection under load		ISO 75	Method A 1.8 MPa	°C	50	50
			Method B 0.45 MPa	°C	130	130
Vicat softening temperature		ISO 306	Method A 10N	°C	175	175
			Method B 50N	°C	140	140
Linear thermal expansion		ISO 11359	23-55 °C; determined on specimen 45·15·10 mm	$10^{-4} \cdot K^{-1}$		1.8
Flammability acc. UL94		IEC 60695	1.6 mm		HB	HB
			3.2 mm		HB	HB
Water absorption		ISO 62	23 °C, saturation [3]	%	1.4	1.5
		determined on 1 mm thick sheets	23 °C, 50% rel. humid.	%	0.5	0.8
Mold shrinkage		ISO 294-4	in flow direction	%	1.7	1.45
		processing cond. acc. to ISO 1874-2	in transverse direction	%	1.7	1.55
Tensile test	Stress at yield	ISO 527-1/2		MPa	37	38
	Strain at yield			%	5	5
	Stress at break			MPa	35	–
	Strain at break			%	45	>50
Tensile modulus		ISO 527-1/2		MPa	1600	1600
CHARPY impact strength [4]		ISO 179/1eU	23 °C	kJ/m^2	N	N
			-30 °C	kJ/m^2	80 C	N
CHARPY notched impact strength [4]		ISO 179/1eA	23 °C	kJ/m^2	60 C	55 P
			-30 °C	kJ/m^2	8 C	15 C

2.4.2 Electrical properties

Property	Test method	Unit sw[2]	L-R1-MHI sw[2]	L-R3-MHI sw[2]
Insulation resistance [5]	IEC 60167	Ω	10^{1}	10^{4}
Volume resistivity	IEC 60093	Ω·cm	10^{1}	10^{4}

[1] Detailed information concerning special properties and applications of these compounds available on request.
[2] sw = black
[3] Platicized compounds were not stored in water because of slight plasticizer migration.
[4] N = no break, P = partial break, C = complete break
[5] Corresponds to R_{OE} DIN 43582: 1983/VDE 0303 part 3

L-R4-MHI sw 2)	L-R7-MHI sw 2)	L-R9-MHI sw 2)	L-R3-EP sw 2)	L-R3-EI sw 2)	LX9102 sw 2)	L-R2-GF25 sw 2)	LX9107 sw 2)	L-CF15 sw 2)
1.06	1.08	1.08	1.17	1.06	1.12	1.27	1.16	1.08
178	178	178	176	178	171	178	178	178
50	50	50	60	60	55	170	164	170
130	130	130	120	130	120	175	178	175
175	175	175	170	175	169	175	–	175
140	140	140	140	140	136	170	–	175
1.8	1.7	1.7	1.5	1.5	1.5	1	–	1.5
HB	HB	HB	HB	HB	HB	HB	–	HB
HB	HB	HB	HB	HB	HB	HB	–	HB
1.5	1.5	1.5	–	1.2	1.5	1.2	–	1.3
0.5	0.7	0.7	0.5	0.5	0.5	0.5	–	0.5
1.75	1.4	1.4	1.3	1.55	1.35	0.3	–	0.15
1.65	1.45	1.45	1.3	1.6	1.5	0.85	–	0.4
36	36	37	–	42	32	–	125	–
8	6	6	–	9	37	–	4.9	–
33	–	–	46	36	39	120	129	120
42	>50	>50	>50	44	>50	5	6.3	5
1250	1400	1400	800	1500	640	6500	9500	8000
N	N	N	N	N	N	75 C	72 C	60 C
N	N	N	N	N	N	70 C	103 C	70 C
55 P	60 P	60 P	38 C	21 C	90 P	12 C	19 C	14 C
12 C	12 C	12 C	4 C	9 C	5 C	11 C	13 C	13 C

L-R4-MHI sw 2)	L-R7-MHI sw 2)	L-R9-MHI sw 2)	L-R3-EP sw 2)	L-R3-EI sw 2)	LX9102 sw 2)	L-R2-GF25 sw 2)	LX9107 sw 2)	L-CF15 sw 2)
10^5	10^7	10^9	10^3	10^3	10^4	10^2	–	10^4
10^5	10^7	10^9	10^3	10^3	10^4	10^2	10^4	10^4

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