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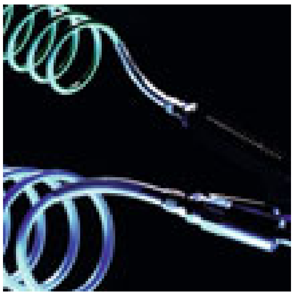
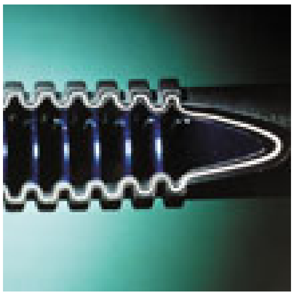
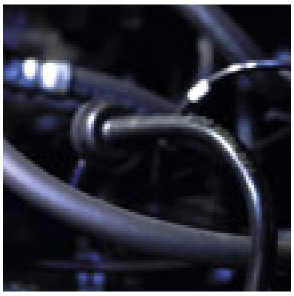
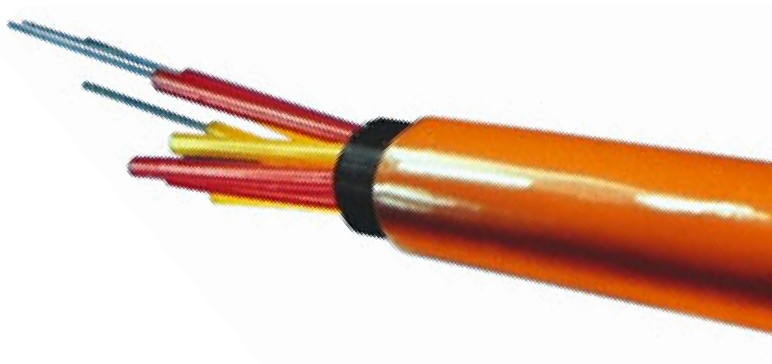
VESTAMID®









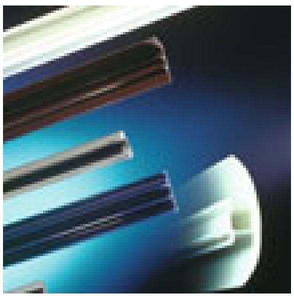


Table of Contents

VESTAMID Polyamide 612

Introduction

Degussa AG's High Performance Polymers Business Unit manufactures a range of polyamide 12 (PA 12), polyamide 612 (PA 612) and polyamide 12 elastomer (PEBA*) compounds, which are supplied under the registered trademark VESTAMID®.

This brochure describes the PA 612 compounds. The other two product families are covered separately in other brochures of the VESTAMID series, "Polyamide 12", and "Polyamide 12 Elastomers". Information about processing VESTAMID can be found in the brochure "Handling and Processing of VESTAMID".

PA 612 is the polycondensation product of 1,6-hexamethylene diamine and 1,12-dodecanedioic acid (1,10-decane dicarboxylic acid):

$$H_2N\text{-}(CH_2)_6\text{-}NH_2 + HOOC\text{-}(CH_2)_{10}\text{-}COOH \rightarrow [NH\text{-}(CH_2)_6\text{-}NH\text{-}CO\text{-}(CH_2)_{10}\text{-}CO]_n$$

The carbonamide groups (-CO-NH-) of the polyamides form hydrogen bridge bonds between the chains of the macromolecules, thereby substantially promoting crystallinity and increasing their strength, melting point, resistance to chemicals, and even water absorption. This is characteristic of all semicrystalline polyamides.

Polyamide 12 has the lowest carbonamide group concentration of all commercially available polyamides, giving it the lowest moisture absorption and largest dimensional stability of parts in changing conditions of ambient humidity. In polyamide 612, the concentration is slightly higher but still well below that of polyamide 6 or polyamide 66.

Molded parts made of polyamide 612 consequently share, nearly unchanged, the same characteristics that are prized in PA 12 molded parts:

- high impact strength
- very good resistance to greases, oils, fuels, hydraulic fluids, water, alkalis, and saline solutions
- very good stress cracking resistance, even when subjected to chemical attack and when used to cover metal parts
- low coefficients of sliding friction and high abrasion resistance, even when running dry

Its advantages over PA 12 exhibit in the

- heat deflection temperature (melting point nearly 40 °C higher)
- tensile and flexural strength
- outstanding recovery at high wet strength

The PA 612 compounds of the VESTAMID D series consequently represent specialty products that complement the comprehensive selection of PA 12 compounds of the VESTAMID L series.

Like all high-performance plastics of the High Performance Polymers Business Unit, VESTAMID compounds satisfy the highest quality standards. Our system for quality assurance is certified according to ISO 9001: 2000 and ISO/TS 16949:2002. In several audits conducted by our customers, this quality management system received excellent ratings.

* PEBA = Polyether block amide according to ISO 1043, part 1.

1 Overview of PA 612 Compounds and Their Applications

1.1 PA 612 compounds and their applications

The PA 612 product line logically complements the comprehensive offering of our PA 12 compounds (see the brochure "VESTAMID Polyamide 12"). Table 1 provides an overview about the characterization of our products and their typical applications. More detailed information about most of our compounds is contained in the comparative tables in chapter 4. For information about new or special products please ask the indicated contacts.

Other properties of VESTAMID 612 compounds and material information on the other products of the High Performance Polymers Business Unit are contained in the plastics database Campus®*), which is updated regularly. You will find Campus on the Internet at www.degussa-hpp.com.

VESTAMID	Characterization	Recomm. for K&K-composite 2)	Processing method 3)	Tensile-Modulus [MPa]	Designation according to ISO 1874-1	Applications
D16	low-viscosity base product		IM,E	2200	PA612, LN, 12-020	monofilaments, bristles with high recovery for paint brushes and tooth brushes
D18	medium-viscosity base product		IM,E	2200	PA612, LN, 14-020	monofilaments, bristles with high recovery for paint brushes and tooth brushes
D22	high-viscosity base product		IM,E	2200	PA612, LN, 18-020	monofilaments, bristles with high recovery for paint brushes and tooth brushes, abrasive bristles, pipes
D26	high-viscosity base product		E	2200	PA612, LN, 22-020	monofilaments
DX9300	low-viscosity, heat-stabilized, with improved release properties		IM	2100	PA612, MHR, 12-020	retainers for qick connectors
X7094 1)	medium-viscosity, heat-stabilized	+	IM,E	2200	PA612, MH, 14-020	profiles
DX9301 1)	medium-viscosity, heat-stabilized, similar to X7094, but suffers less wear from abrasion	+	IM	2700	PA612, MHR, 14-090, CD04	components exposed to friction
DX9322 1)	15% ground-glass fiber reinforced, heat-stabilized	+	IM	3150	PA612, MH, 14-030, GD15	low-warpage housings, coverings (ground glass fiber) with sprayed-on elastomer seals
X7099 1)	20% glass fiber reinforced, heat-stabilized	+	IM	5600	PA612, MH, 14-050, GF20	housings, sealing and damping elements for the automotive industry, noise and vibration-dampened sliding bearings and rollers
DX9321 1)	impact-resistant, 20% glass fiber reinforced, heat-stabilized	+	IM	5700	PA612-HI, MH, 14-050, GF20	housings, coverings
DX9323 1)	impact-resistant, 35% glass fiber reinforced, heat-stabilized	+	IM	8900	PA612-HI, MH, 14-090, GF35	plastic-rubber composites
DX9302 1)	elastomer modified, heat-stabilized	+	E	1150	PA612-HI, EH, xx-010	low-extract windshield wiper lines, corrugated pipes
DX9304 1)	impact-resistant, heat- and light-stabilized		E	1800	PA612-HI, EHL, 18-020	tubing systems subjected to higher temperatures, e.g., hydraulic clutch lines
DX9305 1)	heat- and light-stabilized		E	2250	PA612, EHL, 22-020	tubing systems subjected to higher temperatures, e.g., hydraulic clutch lines

Table 1: PA 612 compounds and their typical applications

1) currently only available in black
2) Plastic-rubber composite
3) IM = Injection Molding; E = Extrusion

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

1.2 Nomenclature

VESTAMID compounds are divided into sales and development products. The composition and manufacturing methods of sales products have been established on the basis of extensive experience and wide acceptance, and these products have a systematic nomenclature. In the case of development products, formulations are still subject to change so that they can be optimized for particular applications.

Sales products
Standard sales products in the VESTAMID 612 series are named with the letter D, identifying dodecanedioic acid as the monomer base.

For unfilled standard products, the next two digits correspond to one tenth of the average viscosity number (J value) measured in m-cresol in accordance with ISO 307. The standard also permits the measurement to take place in 96-percent sulfuric acid instead of m-cresol. Although the two values differ, they correlate strongly[1] (see Figure 1). We do not provide melt flow rates (MFR, MVR), because polyamides have to be viewed as "living polymers" under the specified test conditions. Even minimum water contents in the resins will cause the melt flow rates to become highly variable and non-reproducible without affecting the solution viscosity. In general, the higher the J value (and the two digits in the product name), the higher the molecular weight, melt viscosity, and impact strength can be expected to be.

The final component of the name is the color.
Example: VESTAMID D16 natural color

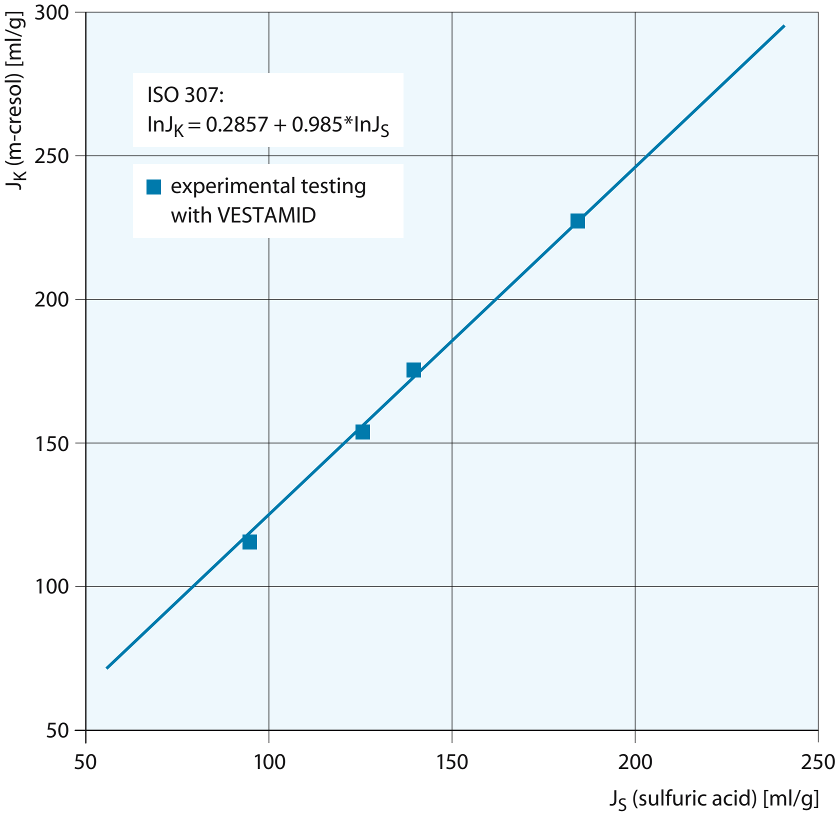


Figure 1: Comparison of the viscosity numbers J, measured in m-cresol and sulfuric acid according to ISO 307

Development products
Development products are created for particular applications. We optimize these products using the experience that we have gained during market introduction. This may result in slight changes to the formulations and manufacturing processes. We immediately notify the affected customers about modifications and inform them about any possible impact on specifications or on quality.

Development products based on PA 612 are named with the letters DX, followed by a four-digit number. The number has no specific meaning in regard to the composition or properties of the product.

Example: Test product, nomenclature VESTAMID DX9300 natural color

*) In the quality test, we only measure the solution viscosity in m-cresol. If desired, the values will be confirmed with additional relevant data in test certificates.

1.3 Delivery and coloring

VESTAMID D 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 D 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.

Similar to other semi-crystalline polyamides, unmodified VESTAMID is colorless when molten and whitish-opaque in its solid state (natural colors). VESTAMID can generally be colored as desired although some special additives may cause restrictions. Most compounds are supplied in their natural colors or as black. Others, such as compounds that have been modified with graphite, have unique colors due to their additives. Colorants containing lead and cadmium are essentially not used.

In appropriate lot sizes, specially colored compounds can be delivered. Please contact the indicated persons for additional information.

VESTAMID resins can also be colored during processing. The preferred method is by using master batches based on PA 612. Dry coloring by tumbling with powdered colorants in a mixer is also possible but inconvenient. Pneumatic conveyance is then ruled out. Colorant pastes or colorant concentrates with a "neutral" base (e.g., polyethylene) may be incompatible with PA 612, ultimately leading to parts with poor characteristics (inhomogeneous color distribution or mechanical failure). Therefore, the compatibility of the colorant paste must definitely be pre-tested.

Our experts will be appreciated to give you additional information and support.

1.4 Processing

PA 612 compounds may only be processed in a dry state at a water content below 0.1%. If this rule is not followed, decomposition and irreversible damage during processing is to be expected. Detailed information about the handling and processing of VESTAMID products and about machine design can be found in the brochure “Handling and Processing of VESTAMID”.

Chapter 1.2, Nomenclature, already mentioned the fundamental interrelationship between viscosity number and melt viscosity. Figures 2 and 3 show the relationships for 260 °C, using the low-viscosity resin VESTAMID D16, the medium-viscosity resin VESTAMID D18, and the high-viscosity resin VESTAMID D22 as examples.

The curve for the reinforced resin VESTAMID X7099 illustrates the influence of 20% glass fibers on the melt viscosity. If necessary, the different viscosity levels can be balanced in the conventional manner by adapting the processing temperature.

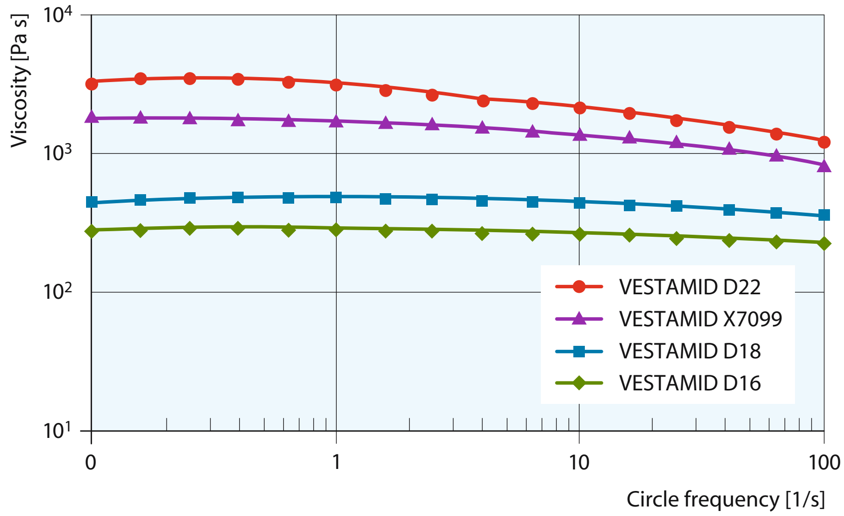


Figure 2: Viscosity curves, T = 260 °C

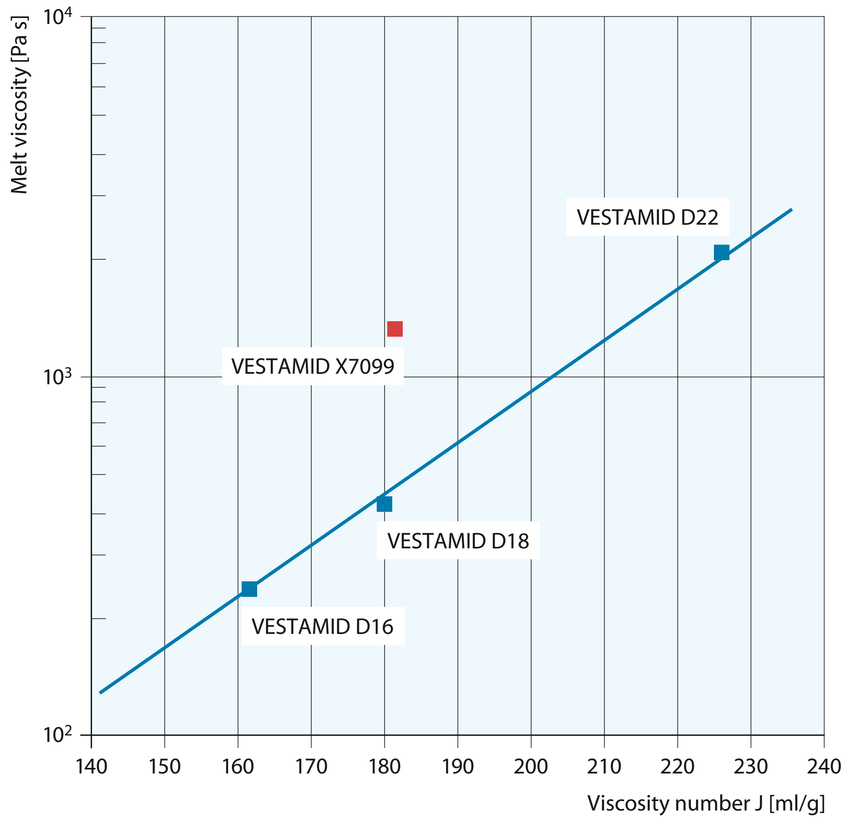


Figure 3: Dependence of the melt viscosity on the solution viscosity (260 °C at 10/s)

2 General Properties

2.1 Physiological and toxicological evaluation

The Environment, Health, Safety & Quality 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 EU Safety Data Sheets for VESTAMID. Please direct all questions on the subject to the indicated contacts.

Food contact—EU-status
Following 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 products of the PA 612 series, like VESTAMID D16, D18, D22, and D26 have been approved by the European Union for direct contact with foodstuffs, since their fundamental monomers hexamethylene diamine and dodecanedioic acid were positively listed in EU Directive 2002/72/EC. The directive specifies a migration value limit of 2.4 mg/kg for hexamethylene diamine, which must be tested on the finished article itself and be kept within limits there.

Plastic additives permitted for food-contact are listed favorably in the "incomplete list" of the EU Plastics Directive. This means that the additives in the EU list and the additives approved by national regulations (in Germany, these are the recommendations of the Federal Institute for Risk Assessment, BfR) may be used. The "incomplete list" of approved substances is scheduled to become a "complete list" by the end of 2006 so that, starting in 2007, only additives appearing in EU list may be used. Because of these continuous revisions, we are currently unable to make any general binding statements about the status of our VESTAMID compounds.

Food contact—FDA-status
Pursuant to the 21st CFR, Section 177.1500 (Nylon Resins) of the Food and Drug Administration (FDA), the United States currently permits PA 612 to come into repeated contact with food at temperatures not to exceed 100 °C. However, the restrictions in Paragraph b(8) must be obeyed. Cold sterilization is permitted.

Medical applications
Directive 93/42/EEC applies to the use of materials in medical applications within the European Union. In August 1994, this directive was incorporated into German law by passage of the *Medizinproduktegesetz* (Medical Devices Act). The pertinent international and national standards, such as ISO 10993 and DIN EN 30993-1, cover the details of the approval process. The most current *Deutsches Arzneibuch* (DAB) (German Pharmacopeia) and *European Pharmacopeia*, Eur. Ph., current edition 2005, 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 experts can provide you information about their experiences with various approval processes.

2.2 Environmental impact and safety

VESTAMID compounds are non-toxic substances that do not constitute any hazard to water and are not governed by any particular safety regulations. They can be disposed of in landfills or incinerated as normal household waste in accordance with local ordinances. Further information can be obtained from the EU safety data sheet for VESTAMID. Recycling is, however, preferred and advisable for economic reasons.

VESTAMID compounds containing flame retardants do not contain polybrominated biphenyls or diphenylethers. No pigments or additives containing cadmium are used.

No dangerous by-products are formed if VESTAMID is processed correctly. 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. Detailed directions about handling VESTAMID products can be found in the brochure "Handling and Processing of VESTAMID".

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 smells.

Most VESTAMID resins are combustible. Flammable gases are released at melt temperatures above 350 °C. Combustion with sufficient air supply produces carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), and nitrogen-containing compounds as end products. Since the spectrum of crack and combustion products greatly depends on the combustion conditions, it is not possible to make any general statements here.

2.3 Influence of temperature on the mechanical properties

Curves of the dynamic shear modulus and of the loss factor tan δ, which are obtained from torsional vibration analysis, provide a first glance at the dependence of the mechanical properties of unreinforced and reinforced VESTAMID 612 compounds on temperature. In Figure 4, it can be clearly seen that PA 612 resins have a higher stiffness than PA 12 resins and that their higher melting point has caused their drop in strength to shift significantly toward higher temperatures. The curve 4 shows the special position of VESTAMID DX9302: this specially modified resin is clearly more flexible and tougher than unmodified PA 612 up to -50 °C, making it the better choice for flexible tubing.

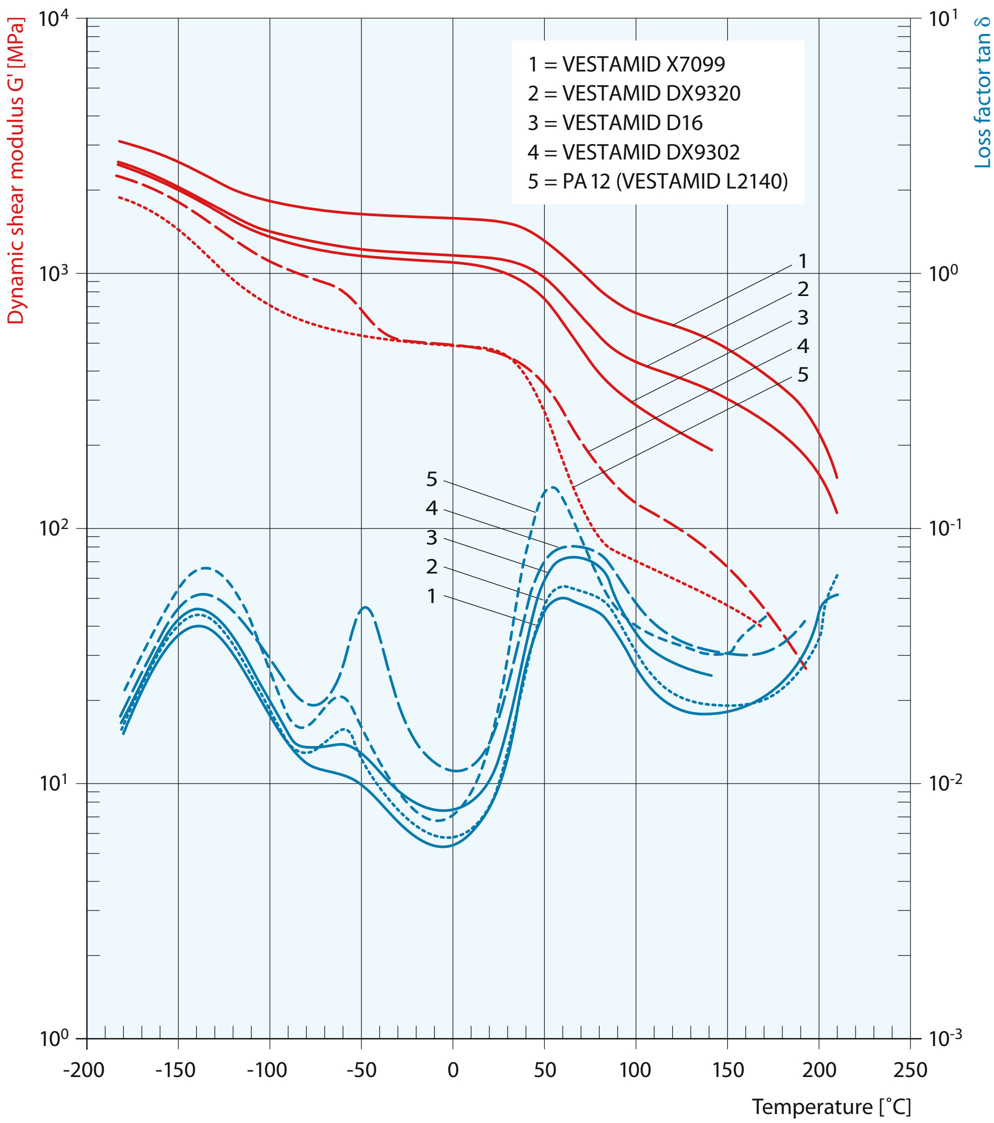


Figure 4: Torsional vibration analysis according to ISO 6721

Figure 5 shows the influence of temperature on the stress-strain behavior. The shape of the curve for VESTAMID D16 is representative of all unreinforced PA 612 compounds.

Plots of the thermal expansion and coefficients of thermal expansion provide information about the dimensional changes caused by temperature (see Figures 6 und 7). The curves for VESTAMID DX9300 are representative for our unfilled PA 612 resins (D16, D18, D22, D26, and also a good approximation for DX9301). The tables in chapter 4 also list the average coefficients of thermal expansion in the temperature range of 23 °C to 55 °C.

If the exposure to extreme temperatures is brief, then the above changes are reversible, with the possible exception of post-shrinkage caused by processing. If components are subjected to thermal stress in the presence of oxygen (air) for a long time, then it is possible that irreversible aging could gradually occur, depending on the duration and temperature. Like any other plastic, VESTAMID will eventually become brittle under such conditions. With the exception of the base products, heat aging inhibitors are added to all VESTAMID 612 resins to stabilize them against the long-term action of heat. In general, processors will add flexible application-oriented stabilizer concentrates to the base products VESTAMID D16, D18, D22, and D26 as necessary during the thermoplastic molding. We can provide advice about the choices upon request.

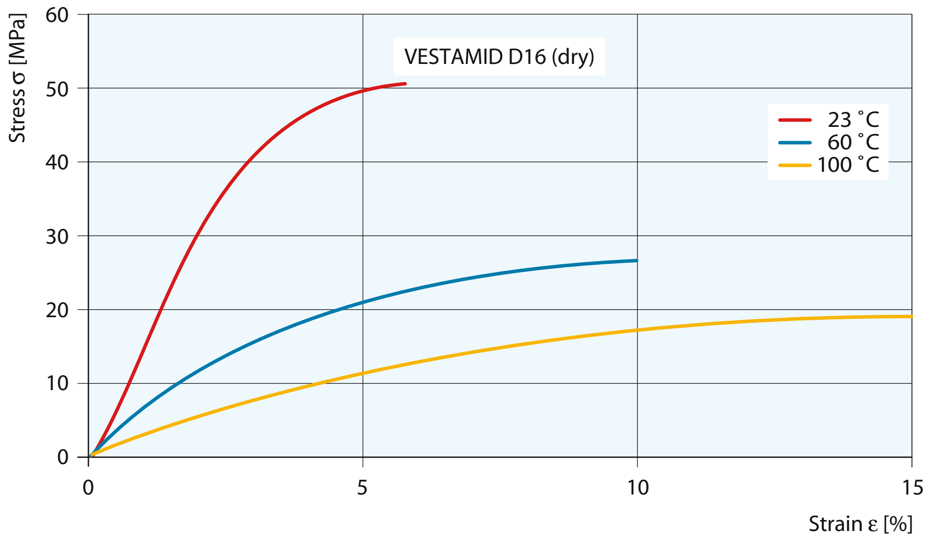


Figure 5: Stress-strain plots from tensile tests according to ISO 527

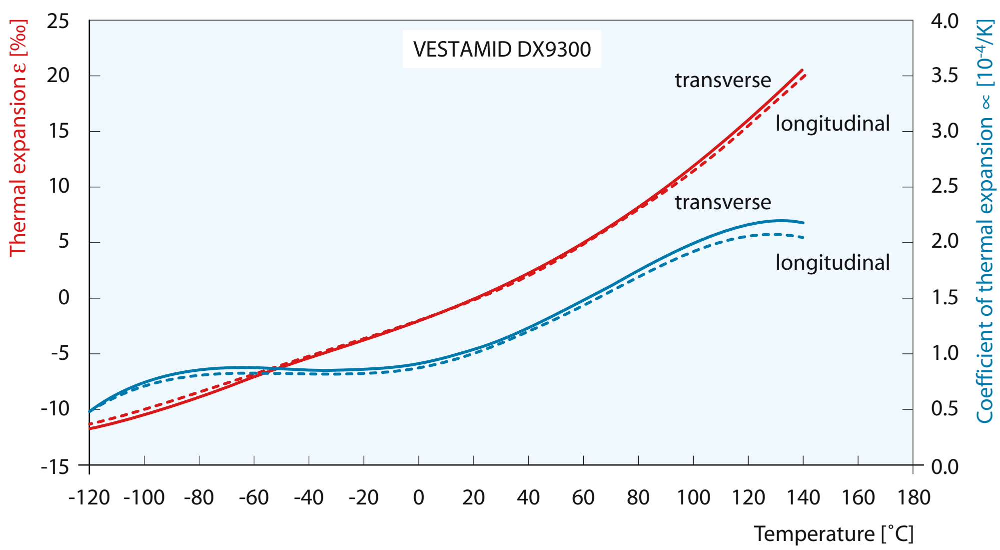


Figure 6: Coefficient of thermal expansion according to ISO 11359

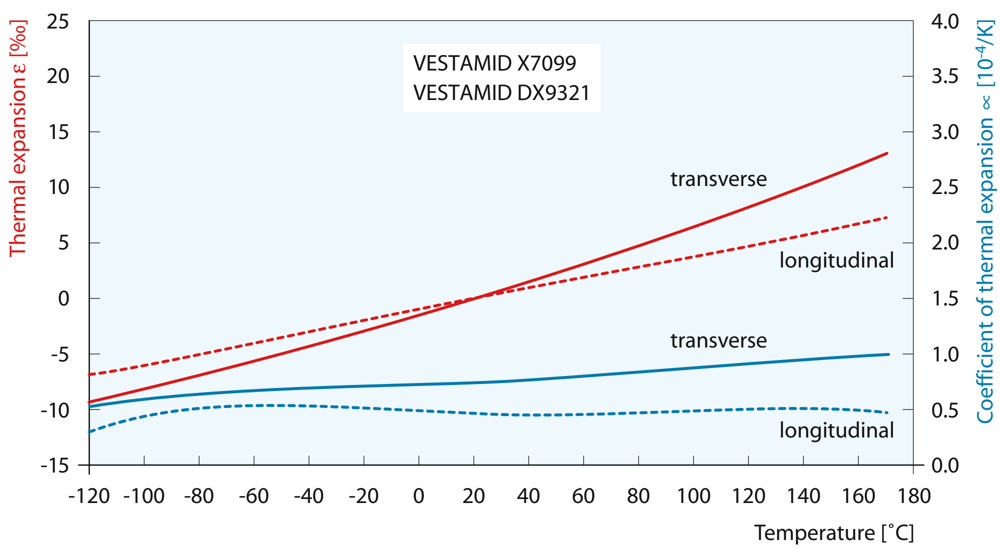


Figure 7: Coefficient of thermal expansion according to ISO 11359

2.4 Long-term properties of PA 612 under load

At elevated temperatures, thermoplastics begin to flow or creep under the influence of stresses, especially when they are unreinforced. PA 612 has a relatively low tendency to creep, but the designer must still take creep resistance into consideration because it declines under continuous load in comparison with short-terme stability. On the other hand, this also means that the initial stress will drop when the strain is held constant. Characteristics necessary to design parts can be taken from Figures 8 through 15, which plot the results of tensile creep tests performed in accordance with ISO 899.

VESTAMID D16

Tensile creep curves according to ISO 899

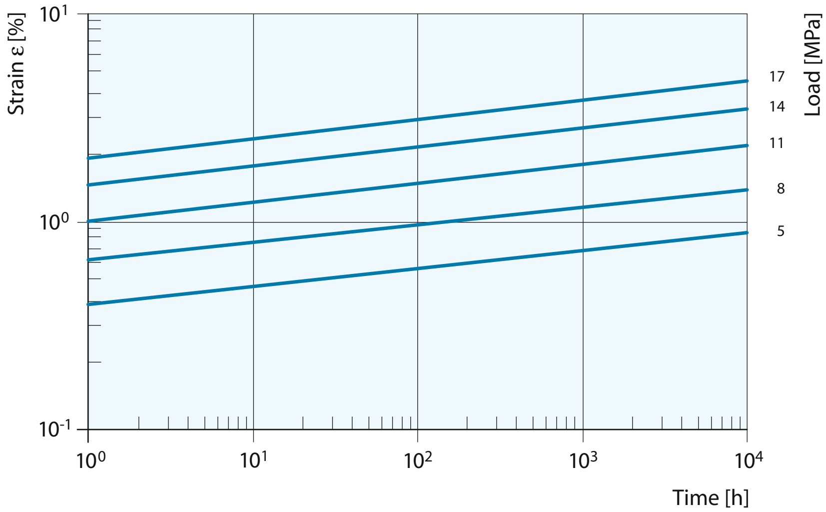


Figure 8: Test conditions 23 °C, 50% r. h.

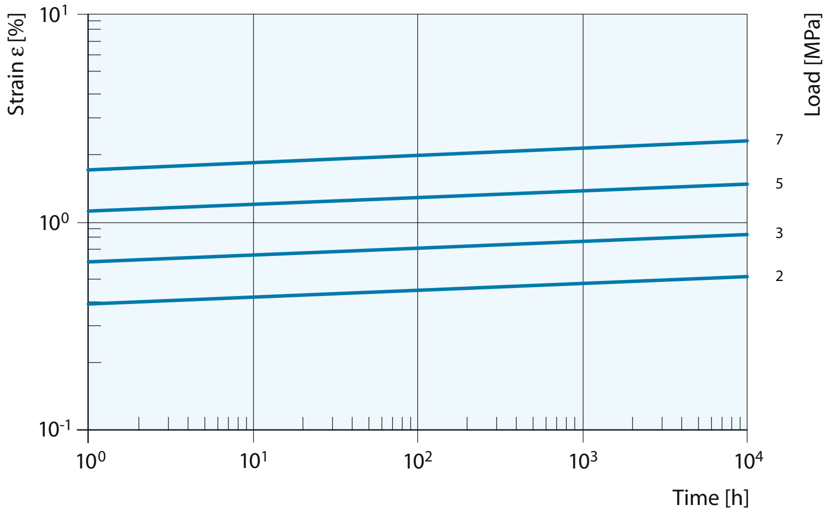


Figure 9: Test condition 60 °C

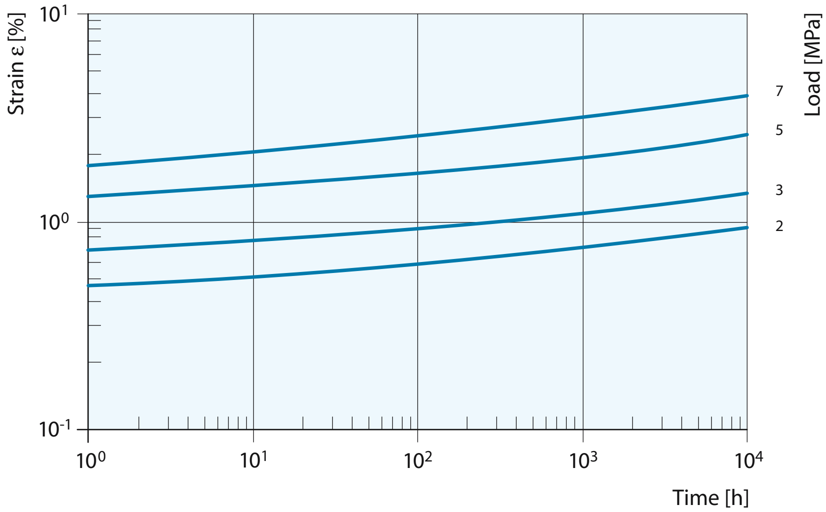


Figure 10: Test condition 100 °C

VESTAMID D16

Tensile creep modulus curves according to ISO 899

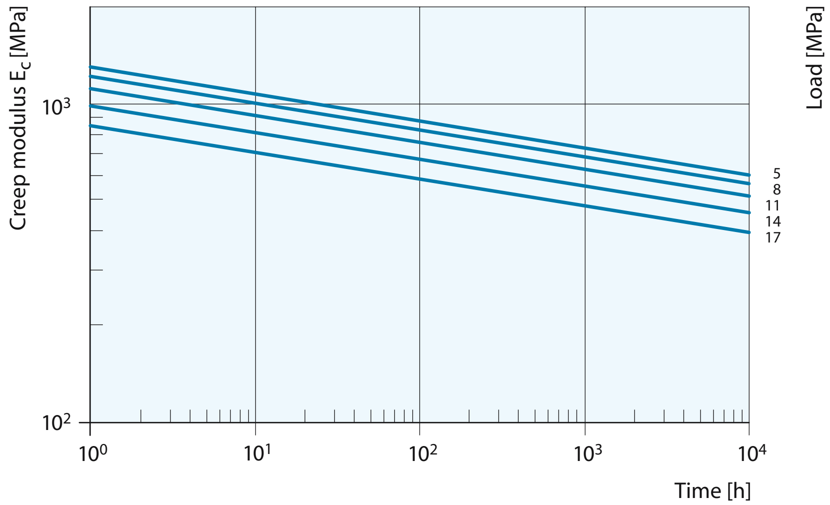


Figure 11: Test conditions 23 °C, 50% r. h.

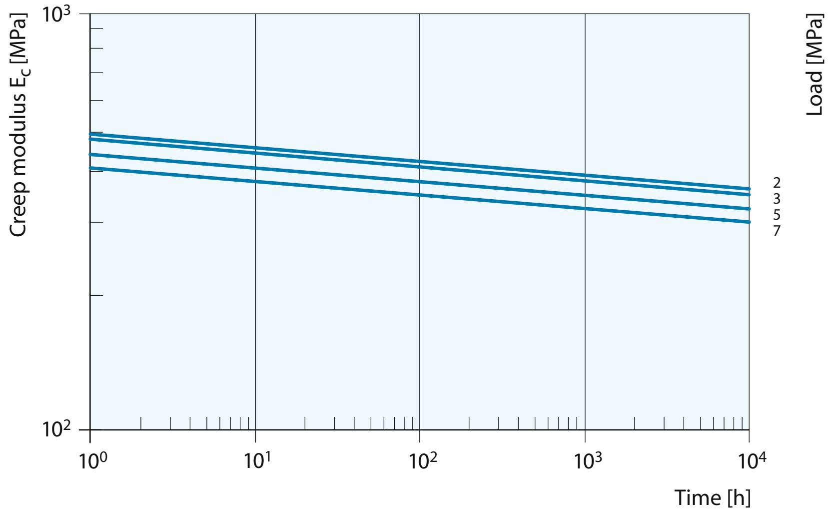


Figure 12: Test condition 60 °C

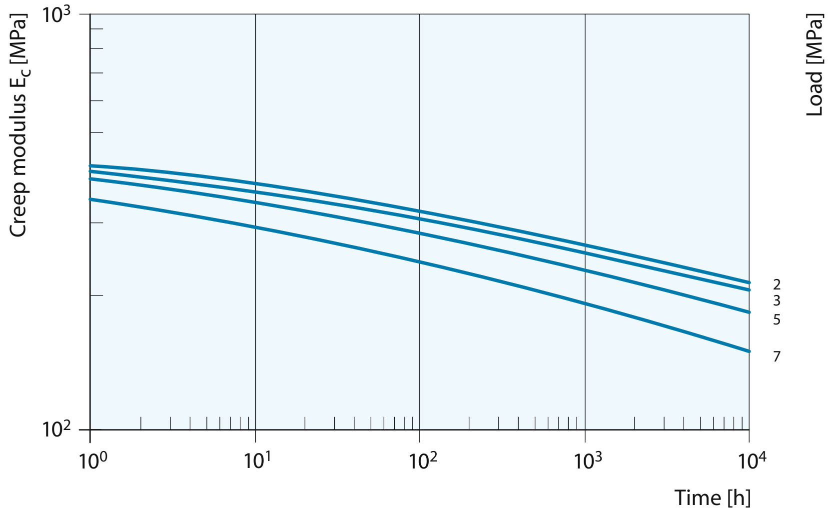


Figure 13: Test condition 100 °C

VESTAMID X7099
black V307171
Tensile creep test according to ISO 899

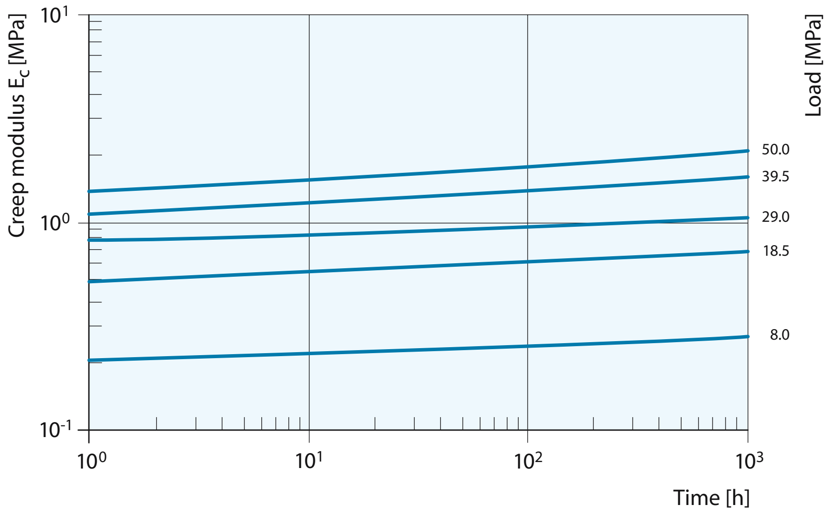


Figure 14: Creep curves, test conditions 23 °C, 50% r. h.

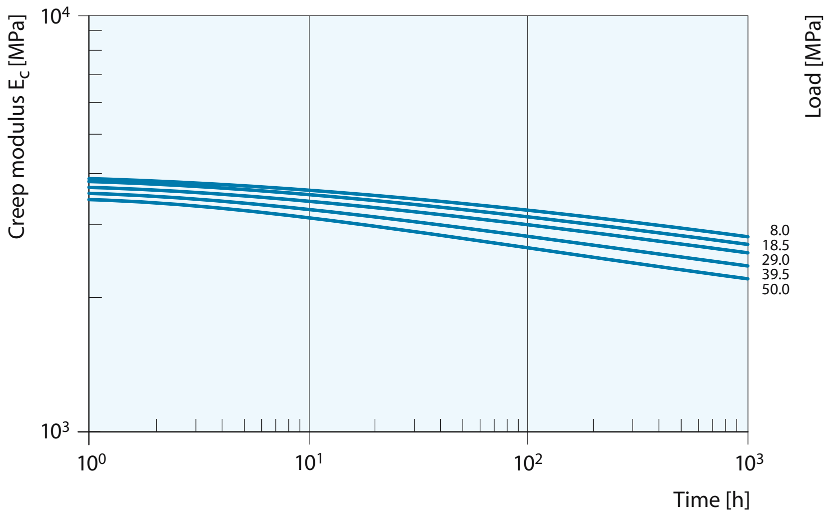
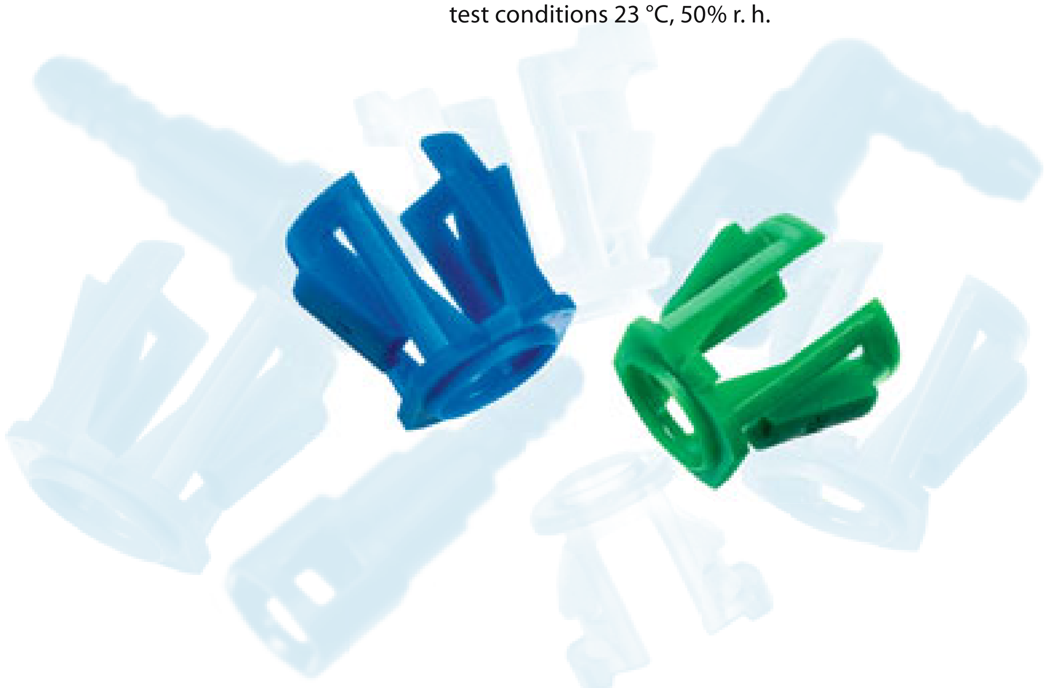


Figure 15: Tensile creep modulus curves, test conditions 23 °C, 50% r. h.



2.5 Influence of ambient humidity

In contrast to PA 6 and 66, PA 612 absorbs very little moisture (see Figures 16 through 18), although it absorbs slightly more than PA 12. It will absorb about 1% water in a standard operating environment of 23°C / 50% relative humidity, and about 2.7% when stored in water. These values are correspondingly lower for filled or glass fiber reinforced resins. Absorption of 1% water causes a volume increase of approximately 0.9%, which corresponds to a change in linear dimension of 0.2-0.3%.

When the product is stored in water, moisture absorption rises with rising temperature. At temperatures above 80 °C, however, components will dry out again in air so the values of the dry parts will have an effect in this case.

Above 0 °C, the absorbed water acts like a small amount of plasticizer. This means that strength and stiffness will drop somewhat and that impact strength and tendency to creep will increase slightly (compare the detailed tables in chapter 4).

Since water absorption is very small, the changes in the electrical parameters at room temperature are also low: the good insulating properties and dielectric strength remain practically unaltered. The effect of water is most recognizable on the slope of the loss factor tan δ.

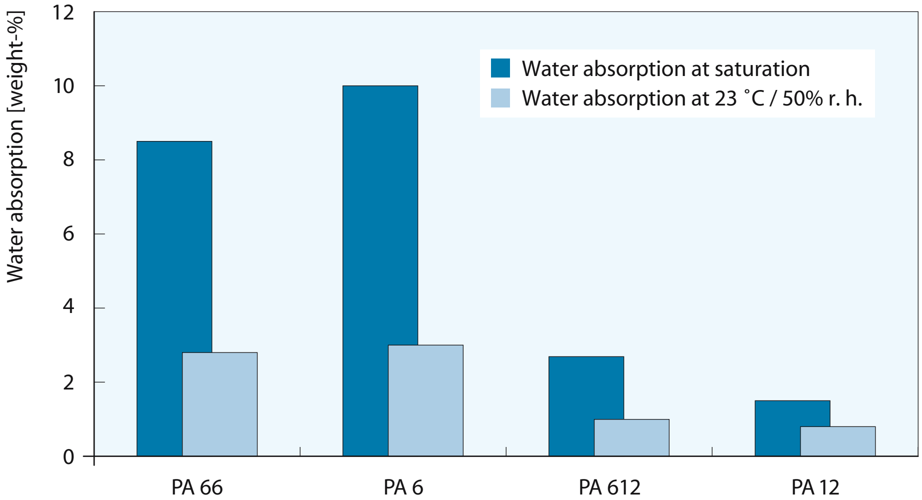


Figure 16: Water absorption of various polyamides

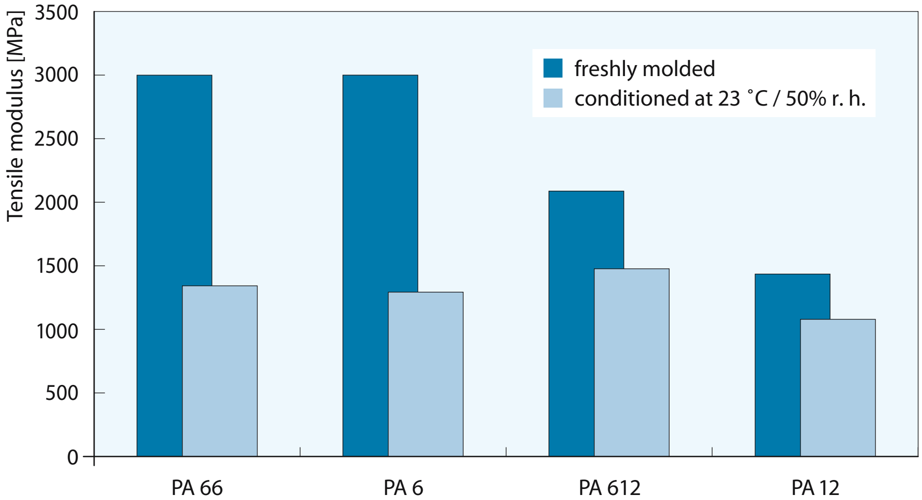


Figure 17: Influence of the water content on the tensile modulus of different polyamides

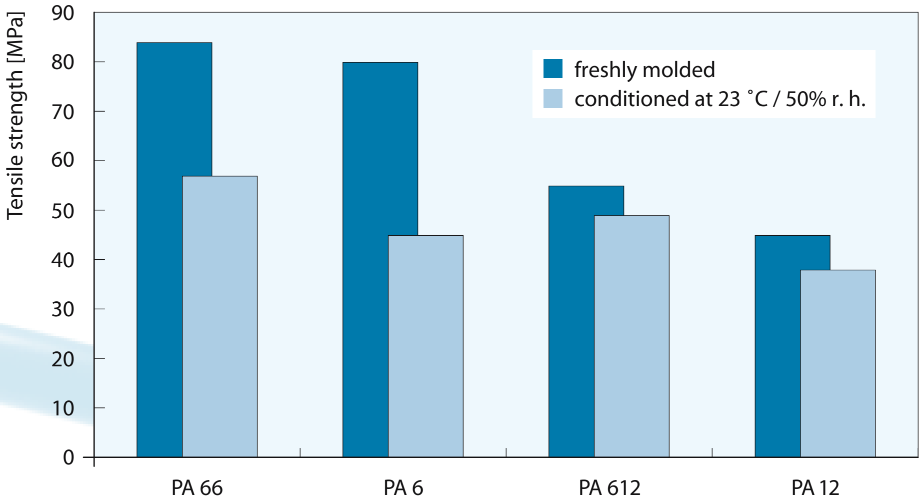


Figure 18: Influence of water content on the tensile strength of different polyamides

2.6 Resistance to chemicals

The chemical resistance of PA 612 is comparable to that of PA 12 (compare Table 7 of the brochure "VESTAMID Polyamide 12"). Polyamide 612 generally displays outstanding resistance to fuels, lubricants, greases, oils, and most industrial solvents. Polar solvents can cause reversible swelling, especially at elevated temperatures. This will generally be connected with a drop in strength (plasticizer effect). In practice, the original characteristics will be restored after the solvent has evaporated.

Liquids that have a particularly high affinity to the carbonamide groups of the polyamides can act as solvents for PA 612 at higher temperatures. Examples are phenols, cresols, benzyl alcohol, and particular chlorohydrocarbons.

Due to their low water absorption, PA 612 compounds exhibit very good resistance to aqueous agents, such as alkali solutions, saline solutions, and cleaners. Their resistance to aqueous acids is limited, depending on the temperature, time, and concentration. In general, concentrated acids will lead to a more or less rapid drop in relative molar mass (embrittlement). Concentrated sulfuric acid and formic acid will dissolve PA 612.

2.7 Abrasion behavior

Polyamides have very high abrasion resistance. This can be determined according to DIN 53754 (Taber) or DIN 53516. The test consists of abrasion from emery grinding. Table 2 shows some typical values and also indicates the effect of fillers and reinforcing materials.

VESTAMID	Modification	Abrasion according to the Taber abrasion test DIN 53 754 at 23 °C [mg/100 revolutions]
DX9300	–	15
DX9301	graphite	9 - 10
DX9322	15% ground glass fibers	7 - 8
DX9321, X7099	20% chopped strands	10

Table 2: Abrasion of PA 612 resins

For bearings or sliding parts, the coefficient of sliding friction is more important than abrasion. This coefficient is low and is comparable to that of PA 12. Since PA 612 is very resistant to greases and lubricants, it is a good material for producing maintenance-free bearings.

3 Plastics-rubber Composites without Adhesives

Several of the VESTAMID D resins have been specially developed to form a direct bond with selected x-NBR, HNBR, FKM, AEM, and newly EPDM rubbers (see Table 1). This utilizes a plastic-rubber composite process (K&K process), which Degussa has patented and which is particularly economical and environmentally friendly. The rubber is first sprayed directly onto moldings of PA 612, without pretreatment or adhesion promoters. A permanent chemical thermoplastic-elastomer composite will then occur during the succeeding peroxide vulcanization step.

In addition to the VESTAMID product group, Degussa also makes other resins based on PPE (VESTORAN®) and blends based on PA 6-3-T (TROGAMID®) to which the plastic-rubber composite process can successfully be applied. Figure 19 illustrates the major processing steps. Detailed information is also provided in the brochure “High Performance Polymers in Plastic-Rubber Composites”. Details can also be obtained from our Market Development Department. Its employees can give you advice about selecting suitable composite partners. Please direct your questions on the subject to the indicated contacts.

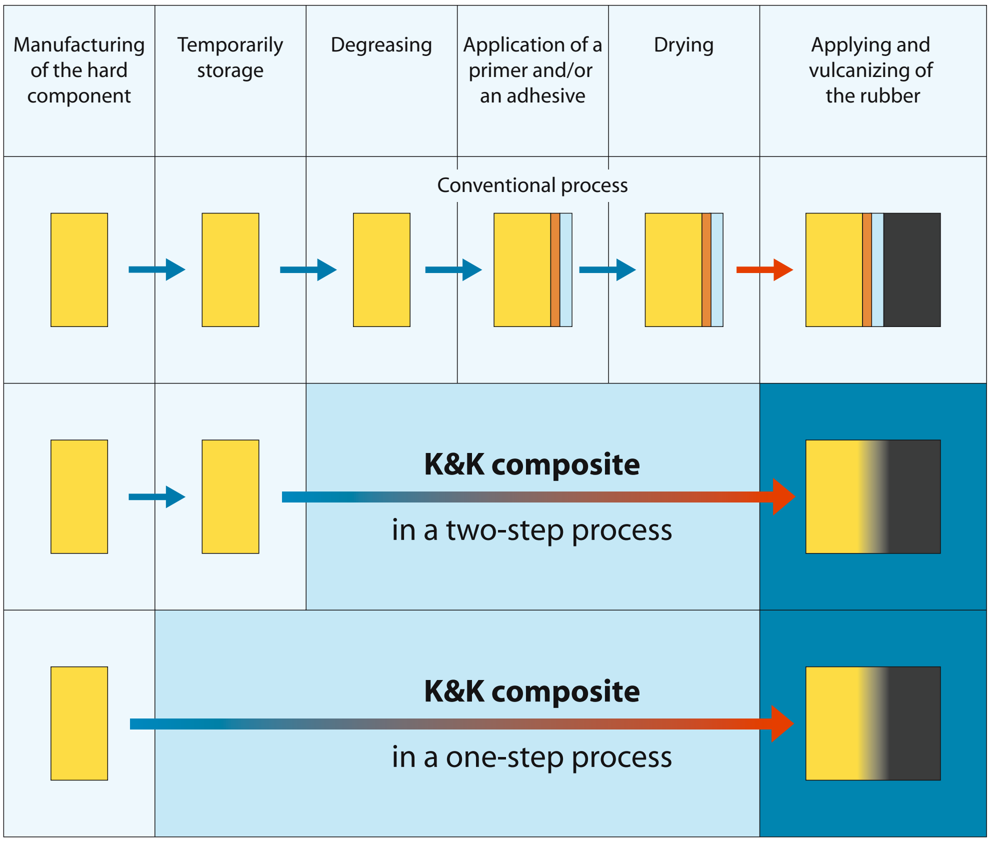


Figure 19: Process diagram of the plastic-rubber composite process

4 Comparative tables of compounds

4.1 Unfilled PA 612 compounds

Property	Test method	Unit	VESTAMID D16		VESTAMID DX9300		VESTAMID D18		VESTAMID X7094 *)		VESTAMID D22		VESTAMID DX9302 *)		VESTAMID D26	VESTAMID DX9304 *)	VESTAMID DX9305 *)
after pretreatment			**dry/freshly molded**	**conditioned[1)]**	**dry/freshly molded**	**conditioned[1)]**	**dry/freshly molded**	**conditioned[1)]**	**dry/freshly molded**	**conditioned[1)]**	**dry/freshly molded**	**conditioned[1)]**	**dry/freshly molded**	**conditioned[1)]**	**dry/freshly molded**	**dry/freshly molded**	**dry/freshly molded**
Physical, thermal, and mechanical properties and combustibility																	
Density 23 °C	ISO 1183	g/cm³	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.02	1.02	1.06	1.04	1.06
Melting temperature peak temperature, 2nd heating	ISO 11357	°C	215	215	215	215	215	215	215	215	215	215	-	-	215	213	213
Heat deflection temperature under load [2)] method A 1.8 MPa	ISO 75-1/-2	°C	65 (75)	55	65 (75)	55	60 (75)	55	60 (75)	55	60 (75)	55	50	-	-	-	60
method B 0.45 MPa		°C	150 (170)	150 (170)	155 (170)	155 (170)	140 (170)	140 (170)	150 (170)	150 (170)	140 (170)	140 (170)	140	-	-	-	160
Vicat softening temperature method B 50 N	ISO 306	°C	180	180	180	180	180	180	185	185	180	180	110	110	-	-	-
Coefficient of linear thermal expansion 23 - 55 °C	ISO 11359	10^{-4} K^{-1}	1.3	-	1.3	-	1.3	-	-	-	1.3	-	1.7	-	-	1.48	-
Flammability acc. UL94 1.6 mm	IEC 60695		HB	HB	HB	HB	HB	HB	HB	HB	HB	HB	HB	-	-	-	-
3.2 mm			HB	HB	HB	HB	HB	HB	HB	HB	HB	HB	HB	-	-	-	-
Water absorption 23 °C, saturation	ISO 62	%	2.6	-	2.6	-	2.7	-	2.8	-	2.7	-	2.2	-	2.7	2.7	2.7
Moisture absorption 23 °C 50% r. h.	ISO 62	%	1.0	-	1.0	-	1.0	-	1.0	-	1.0	-	0.5	-	1.0	1.0	1.0
Mold shrinkage in flow direction	specimen 127*12.7*3.2 mm³	%	1.4	-	1.1	-	1.3	-	1.3	-	1.3	-	1.9	-	-	-	-
in transverse direction	processing acc. to ISO 1874-2	%	1.0	-	1.5	-	1.1	-	1.1	-	1.1	-	1.4	-	-	-	-
Tensile test Stress at yield	ISO 527-2/1A	MPa	58	53	59	52	60	52	60	53	60	49	30	26	60	50	60
Strain at yield		%	5	16	5	20	4	20	5	20	4	20	15	23	4.2	5.0	4.3
Strain at break		%	> 50	> 50	> 50	> 50	> 50	> 50	8	30	> 50	> 50	> 50	> 50	> 50	> 50	> 50
Tensile modulus	ISO 527-2/1A	MPa	2200	1700	2100	1700	2200	1700	2200	1700	2200	1700	1150	850	2200	1800	2250
CHARPY impact strength [3)] 23 °C	ISO 179/1eU	kJ/m²	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
-30 °C		kJ/m²	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CHARPY notched impact strength [3)] 23 °C	ISO 179/1eA	kJ/m²	5C	6C	6C	8C	6C	9C	6C	9C	7C	10C	90P	100P	8C	50P	6C
-30 °C		kJ/m²	6C	6C	6C	6C	6C	7C	7C	7C	7C	6C	19C	17P	-	30C	6C
Electrical properties																	
Relative permittivity 100 Hz	IEC 60250		3.8	4.5	4.0	-	3.8	-	4.4	-	3.8	5.0	3.8	-	-	-	-
1 MHz			3.2	4.1	2.9	-	3.4	-	3.9	-	3.0	3.7	3.0	-	-	-	-
Dissipation factor 100 Hz	IEC 60250	10^{-4}	240	590	440	-	260	-	590	-	230	650	46	-	-	-	-
1 MHz		10^{-4}	290	510	330	-	310	-	390	-	290	550	30	-	-	-	-
Dielectric strength K20/P50	IEC 60243-1	kV/mm	28	27	29	-	28	-	30	-	27	27	41	-	-	-	-
Comparative tracking index CTI test solution A 100 drops value	IEC 60112		> 600	> 600	> 600	-	> 600	-	> 600	-	> 600	> 600	>600	-	-	-	-
Volume resistivity	IEC 60093	Ohm cm	10^{15}	10^{14}	10^{14}	-	-	-	10^{14}	-	10^{15}	10^{14}	10^{14}	-	-	-	-
Electrolytic corrosion effect	IEC 60426	step	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	AN 1.2	-	-	-	-

1) conditioned at 23 °C / 50% relative humidity to constant weight
2) measured freshly molded; values in parenthesis after conditioning at 180 °C/60 min
3) N = no break, P = partial break, C = complete break incl. hinge break H

*) currently only available in black

4 Comparative Tables of Compounds

4.1 Unfilled PA 612 compounds

Property		Test method	Unit	D16		DX9300		D18
after pretreatment				**dry/freshly molded**	**conditioned[1]**	**dry/freshly molded**	**conditioned[1]**	**dry/freshly molded**
Physical, thermal, and mechanical properties and combustibility								
Density	23 °C	ISO 1183	g/cm^3	1.06	1.06	1.06	1.06	1.06
Melting temperature		ISO 11357						
peak temperature, 2nd heating			°C	215	215	215	215	215
Heat deflection temperature under load [2]		ISO 75-1/-2						
method A	1.8 MPa		°C	65 (75)	55	65 (75)	55	60 (75)
method B	0.45 MPa		°C	150 (170)	150 (170)	155 (170)	155 (170)	140 (170)
Vicat softening temperature		ISO 306						
method B	50 N		°C	180	180	180	180	180
Coefficient of linear thermal expansion	23 - 55 °C	ISO 11359	10^{-4} K^{-1}	1.3	-	1.3	-	1.3
Flammability acc. UL94	1.6 mm	IEC 60695		HB	HB	HB	HB	HB
	3.2 mm			HB	HB	HB	HB	HB
Water absorption	23 °C, saturation	ISO 62	%	2.6	-	2.6	-	2.7
Moisture absorption	23 °C 50% r. h.	ISO 62	%	1.0	-	1.0	-	1.0
Mold shrinkage		specimen						
in flow direction		127*12.7*3.2 mm^3	%	1.4	-	1.1	-	1.3
in transverse direction		processing acc. to ISO 1874-2	%	1.0	-	1.5	-	1.1
Tensile test		ISO 527-2/1A						
Stress at yield			MPa	58	53	59	52	60
Strain at yield			%	5	16	5	20	4
Strain at break			%	> 50	> 50	> 50	> 50	> 50
Tensile modulus		ISO 527-2/1A	MPa	2200	1700	2100	1700	2200
CHARPY impact strength [3]	23 °C	ISO 179/1eU	kJ/m^2	N	N	N	N	N
	-30 °C		kJ/m^2	N	N	N	N	N
CHARPY notched impact strength [3]	23 °C	ISO 179/1eA	kJ/m^2	5C	6C	6C	8C	6C
	-30 °C		kJ/m^2	6C	6C	6C	6C	6C
Electrical properties								
Relative permittivity	100 Hz	IEC 60250		3.8	4.5	4.0	-	3.8
	1 MHz			3.2	4.1	2.9	-	3.4
Dissipation factor	100 Hz	IEC 60250	10^{-4}	240	590	440	-	260
	1 MHz		10^{-4}	290	510	330	-	310
Dielectric strength	K20/P50	IEC 60243-1	kV/mm	28	27	29	-	28
Comparative tracking index	CTI	IEC 60112						
test solution A	100 drops value			> 600	> 600	> 600	-	> 600
Volume resistivity		IEC 60093	Ohm cm	10^{15}	10^{14}	10^{14}	-	-
Electrolytic corrosion effect		IEC 60426	step	A1	A1	A1	A1	A1

1) conditioned at 23 °C / 50% relative humidity to constant weight
2) measured freshly molded; values in parenthesis after conditioning at 180 °C/60 min
3) N = no break, P = partial break, C = complete break incl. hinge break H

VESTAMID									
	X7094 *)		D22		DX9302 *)		D26	DX9304 *)	DX9305 *)
conditioned[1)]	dry/freshly molded	conditioned[1)]	dry/freshly molded	conditioned[1)]	dry/freshly molded	conditioned[1)]	dry/freshly molded	dry/freshly molded	dry/freshly molded
1.06	1.06	1.06	1.06	1.06	1.02	1.02	1.06	1.04	1.06
215	215	215	215	215	-	-	215	213	213
55	60 (75)	55	60 (75)	55	50	-	-	-	60
140 (170)	150 (170)	150 (170)	140 (170)	140 (170)	140	-	-	-	160
180	185	185	180	180	110	110	-	-	-
-	-	-	1.3	-	1.7	-	-	1.48	-
HB	HB	HB	HB	HB	HB	-	-	-	-
HB	HB	HB	HB	HB	HB	-	-	-	-
-	2.8	-	2.7	-	2.2	-	2.7	2.7	2.7
-	1.0	-	1.0	-	0.5	-	1.0	1.0	1.0
-	1.3	-	1.3	-	1.9	-	-	-	-
-	1.1	-	1.1	-	1.4	-	-	-	-
52	60	53	60	49	30	26	60	50	60
20	5	20	4	20	15	23	4.2	5.0	4.3
> 50	8	30	> 50	> 50	> 50	> 50	> 50	> 50	> 50
1700	2200	1700	2200	1700	1150	850	2200	1800	2250
N	N	N	N	N	N	N	N	N	N
N	N	N	N	N	N	N	N	N	N
9C	6C	9C	7C	10C	90P	100P	8C	50P	6C
7C	7C	7C	7C	6C	19C	17P	-	30C	6C
-	4.4	-	3.8	5.0	3.8	-	-	-	-
-	3.9	-	3.0	3.7	3.0	-	-	-	-
-	590	-	230	650	46	-	-	-	-
-	390	-	290	550	30	-	-	-	-
-	30	-	27	27	41	-	-	-	-
-	> 600	-	> 600	> 600	>600	-	-	-	-
-	10^{14}	-	10^{15}	10^{14}	10^{14}	-	-	-	-
A1	A1	A1	A1	A1	AN 1.2	-	-	-	-

*) currently only available in black

4.2 Filled and reinforced PA 612 compounds

Property with fillers-/reinforcing materials		Test method	Unit	VESTAMID DX9301 *) 4% graphite	DX9322 *) 15% ground glass fibers		X7099 *) 20% glass fibers		DX9321 *) 20% glass fibers		DX9323 *) 35% glass fibers	
after pretreatment				dry/freshly molded	dry/freshly molded	conditioned[1]	dry/freshly molded	conditioned[1]	dry/freshly molded	conditioned[1]	dry/freshly molded	conditioned[1]
Physical, thermal, and mechanical properties and combustibility												
Density	23 °C	ISO 1183	g/cm^3	1.09	1.17	1.17	1.20	1.20	1.19	1.19	1.33	1.33
Melting temperature		ISO 11357										
peak temperature, 2^{nd} heating			°C	215	215	215	210	210	215	215	215	215
Heat deflection temperature under load		ISO 75-1/-2										
method A	1.8 MPa		°C	85	114	114	190	190	189	189	196	196
method B	0.45 MPa		°C	185	186	186	210	210	208	208	213	213
Vicat softening temperature		ISO 306										
method B	50 N		°C	187	194	193	205	205	207	207	209	209
Coefficient of linear thermal expansion	23 - 55 °C	ISO 11359										
	longitudinal		10^{-4} K^{-1}	1.3	1.0	-	0.5	-	0.5	-	0.5	-
	transverse		10^{-4} K^{-1}	1.1	0.6	-	0.7	-	0.7		0.8	-
Flammability acc. UL94	1.6 mm	IEC 60695		-	HB	HB	HB	HB	HB	HB	HB	HB
	3.2 mm			-	-	-	HB	-	-	-	HB	HB
Water absorption	23 °C, saturation	ISO 62	%	2.7	2.4	-	2.0	-	2.0	-	1.9	-
Moisture absorption	23 °C, 50 % r. h.	ISO 62	%	1.0	0.9	-	0.8	-	0.8	-	0.8	-
Mold shrinkage		specimen										
in flow direction		127*12.7*3.2 mm^3	%	1.2	1.92	-	0.55	-	0.66	-	0.35	-
in transverse direction		processing acc. to ISO 1874-2	%	1.4	0.93	-	1.05	-	0.88	-	1.02	-
Tensile test		ISO 527-2/1A										
Stress at yield			MPa	-	63	53	-	-	-	90	-	-
Strain at yield			%	-	8	12	-	-	-	5	-	-
Stress at break			MPa	65	59	47	118	-	115	86	148	126
Strain at break			%	7	18	23	5	-	5	10	5	5
Tensile modulus		ISO 527-2/1A	MPa	2700	3150	2650	5600	-	5700	4700	8900	7400
CHARPY impact strength [2)]	23 °C	ISO 179/1eU	kJ/m^2	115C	46C	96C	80C	-	93C	93C	90C	86C
	-30 °C		kJ/m^2	110C	43C	48C	60C	-	106C	102C	105C	97C
CHARPY notched impact strength [2)]	23 °C	ISO 179/1eA	kJ/m^2	4C	4C	5C	10C	-	18C	19C	22C	21C
	-30 °C		kJ/m^2	3C	3C	3C	7C	-	11C	11C	15C	14C
Electrical properties												
Relative permittivity	100 Hz	IEC 60250		-	4.3	-	4.4	-	4.4	-	4.8	-
	1 MHz			-	3.1	-	3.9	-	3.1	-	3.6	-
Dissipation factor	100 Hz	IEC 60250	10^{-4}	-	430	-	650	-	500	-	610	-
	1 MHz		10^{-4}	-	493	-	430	-	470	-	320	-
Dielectric strength	K20/P50	IEC 60243-1	kV/mm	-	-	-	38	-	-	-	39	-
Comparative tracking index	CTI	IEC 60112										
test solution A	50 drop value			-	> 600	-	-	-	> 600	-	> 600	-
	100 drop value			-	575	-	-	-	600	-	575	-
Volume resistivity		IEC 60093	Ohm cm	-	10^{14}	-	10^{14}	-	10^{14}	-	10^{14}	-

[1)] conditioned at 23 °C / 50% relative humidity to constant weight
[2)] C = complete break incl. hinge break H

*) currently only available in black

4.2 Filled and reinforced PA 612 compounds

Property with fillers-/reinforcing materials		Test method	Unit	DX9301 *) 4% graphite
after pretreatment				**dry/freshly molded**
Physical, thermal, and mechanical properties and combustibility				
Density	23 °C	ISO 1183	g/cm³	1.09
Melting temperature		ISO 11357		
peak temperature, 2nd heating			°C	215
Heat deflection temperature under load		ISO 75-1/-2		
method A	1.8 MPa		°C	85
method B	0.45 MPa		°C	185
Vicat softening temperature		ISO 306		
method B	50 N		°C	187
Coefficient of linear thermal expansion	23 - 55 °C	ISO 11359		
	longitudinal		10^{-4} K^{-1}	1.3
	transverse		10^{-4} K^{-1}	1.1
Flammability acc. UL94	1.6 mm	IEC 60695		-
	3.2 mm			-
Water absorption	23 °C, saturation	ISO 62	%	2.7
Moisture absorption	23 °C, 50 % r. h.	ISO 62	%	1.0
Mold shrinkage		specimen		
in flow direction		127*12.7*3.2 mm³	%	1.2
in transverse direction		processing acc. to ISO 1874-2	%	1.4
Tensile test		ISO 527-2/1A		
Stress at yield			MPa	-
Strain at yield			%	-
Stress at break			MPa	65
Strain at break			%	7
Tensile modulus		ISO 527-2/1A	MPa	2700
CHARPY impact strength 2)	23 °C	ISO 179/1eU	kJ/m²	115C
	-30 °C		kJ/m²	110C
CHARPY notched impact strength 2)	23 °C	ISO 179/1eA	kJ/m²	4C
	-30 °C		kJ/m²	3C
Electrical properties				
Relative permittivity	100 Hz	IEC 60250		-
	1 MHz			-
Dissipation factor	100 Hz	IEC 60250	10^{-4}	-
	1 MHz		10^{-4}	-
Dielectric strength	K20/P50	IEC 60243-1	kV/mm	-
Comparative tracking index	CTI	IEC 60112		
test solution A	50 drop value			-
	100 drop value			-
Volume resistivity		IEC 60093	Ohm cm	-

1) conditioned at 23 °C / 50% relative humidity to constant weight
2) C = complete break incl. hinge break H

VESTAMID							
DX9322 *) 15% ground glass fibers		X7099 *) 20% glass fibers		DX9321 *) 20% glass fibers		DX9323 *) 35% glass fibers	
dry/freshly molded	conditioned[1)]	dry/freshly molded	conditioned[1)]	dry/freshly molded	conditioned[1)]	dry/freshly molded	conditioned[1)]
1.17	1.17	1.20	1.20	1.19	1.19	1.33	1.33
215	215	210	210	215	215	215	215
114	114	190	190	189	189	196	196
186	186	210	210	208	208	213	213
194	193	205	205	207	207	209	209
1.0	-	0.5	-	0.5	-	0.5	-
0.6	-	0.7	-	0.7		0.8	-
HB	HB	HB	HB	HB	HB	HB	HB
-	-	HB	-	-	-	HB	HB
2.4	-	2.0	-	2.0	-	1.9	-
0.9	-	0.8	-	0.8	-	0.8	-
1.92	-	0.55	-	0.66	-	0.35	-
0.93	-	1.05	-	0.88	-	1.02	-
63	53	-	-	-	90	-	-
8	12	-	-	-	5	-	-
59	47	118	-	115	86	148	126
18	23	5	-	5	10	5	5
3150	2650	5600	-	5700	4700	8900	7400
46C	96C	80C	-	93C	93C	90C	86C
43C	48C	60C	-	106C	102C	105C	97C
4C	5C	10C	-	18C	19C	22C	21C
3C	3C	7C	-	11C	11C	15C	14C
4.3	-	4.4	-	4.4	-	4.8	-
3.1	-	3.9	-	3.1	-	3.6	-
430	-	650	-	500	-	610	-
493	-	430	-	470	-	320	-
-	-	38	-	-	-	39	-
> 600	-	-	-	> 600	-	> 600	-
575	-	-	-	600	-	575	-
10^{14}	-	10^{14}	-	10^{14}	-	10^{14}	-

*) currently only available in black

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