Grilamid TR

Transparent polyamide for the most exacting requirements

Grilamid TR®

EMS

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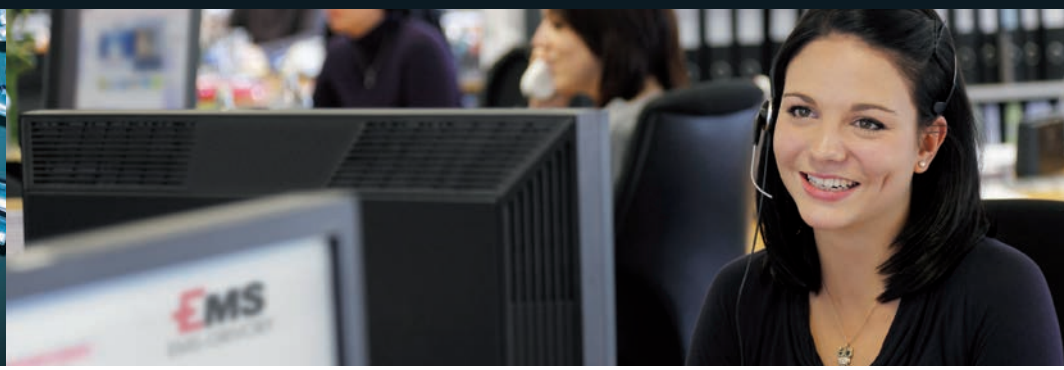


EMS-GRIVORY – the leading specialist in high-performance polyamides

EMS-GRIVORY is currently a world leader in the development and manufacture of high grade polymers based on polyamides. In addition to the amorphous, transparent Grilamid TR polyamides, EMS-GRIVORY also manufactures and sells the thermoplastics Grilamid (polyamide 12), Grivory (partially aromatic polyamides) and Grilon (polyamide 6 and 66 products).

The name EMS-GRIVORY is synonymous with both the latest plastics technology and polymers whose specific properties open up new application areas. Future oriented concept designs are assessed on the basis of a number of criteria including their potential for offering an optimal combination of functionality, safety and cost-effectiveness. Our product ideas and our application solutions are developed with this aim in mind. The technical capabilities of our development departments, combined with our specialists' expertise, result in successful applications which are developed in close cooperation with our customers. These applications are found in many fields including in particular automotive construction, electrical/electronics technologies, industry, sanitary fittings, optics, sport & leisure and the packaging industry.

Grilamid TR – the transparent polyamide

EMS-GRIVORY markets its amorphous, transparent polyamides under the brand name Grilamid TR. These products are transparent polyamides which can be processed using thermoplastic methods and which are based on aromatic and cycloaliphatic units, combining a range of remarkable properties. Grilamid TR belongs to the group of amorphous homo and copolyamides.

A brief history

In the 1970s, EMS developed a new type of polymer which became the forerunner for a transparent, amorphous polyamide practically unknown at that time. Since there were no monomer production units available at that time, EMS manufactured these in its own laboratories. In 1975, a copolyamide – today known as Grilamid TR 55 – was first introduced to the market.

A little later, the monomers also became commercially available in the required quality, laying the foundation for widespread marketing. The first products made of Grilamid TR were completely transparent shirt buttons which could stand up to a washing machine. This was a real novelty at the time because this excellent resistance to hydrolysis had been previously unknown for a transparent polyamide. The further potential of this product was swiftly recognised and many applications followed, some of which were truly groundbreaking. Thanks to both its chemical and crush resistance, Grilamid TR helped data-transmission technology along the road to success by providing, for example, the protective tubing for fibre-optic waveguides.

Various modifications were then made to the basic grade in order to meet customers' specific requirements and cover additional fields of application more effectively. This portfolio was continually developed and expanded by EMS through the addition of new polymers, in particular the homopolyamide Grilamid TR 90. Today, EMS-GRIVORY offers the widest polyamide range worldwide with innovative products constantly being added to the portfolio.

Grilamid TR – Basic properties

Grilamid TR at a glance

Compared to the known semi-crystalline polyamides, crystallisation of the macromolecules is prevented by carefully selecting the monomers, resulting in polymers with an amorphous structure which brings a strikingly high level of transparency.

Grilamid TR grades combine the properties of semi-crystalline polyamides with those of amorphous polymers in a unique way currently not achieved by any other transparent thermoplastics.

In addition to transparency, other outstanding properties include excellent flexural fatigue strength, which facililates applications under dynamic loading, and high resis-tance to chemicals, resulting in low susceptability to stress cracking when in contact with media.
The well known tendency of amorphous thermoplastics to suffer from stress cracking, which is very often at the root of component failure, is a rare phenomenon in the case of Grilamid TR.

The cycloaliphatic Grilamid TR 90 grades also offer excellent weathering and UV resistance.

Properties of Grilamid TR

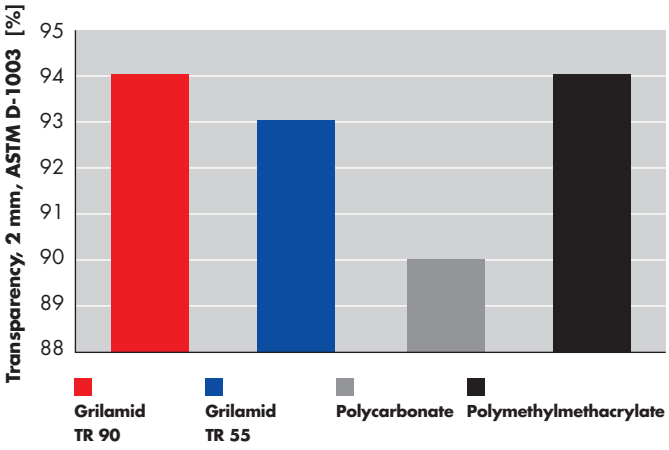
- high transparency, even with thick walled components
- clear and light inherent colour
- resistance to chemicals and stress cracking
- very high flexural fatigue strength
- very good toughness, even at low temperatures
- dimensional stability and dynamic strength
- light weight due to low density
- low water absorption compared to standard polyamides
- high heat deflection temperature thanks to high glass transition temperatures
- low and mainly isotropic shrinkage
- easy processing
- easily colourable

Comparison with other amorphous plastic materials

Property	TR 55	TR 90	Poly-carbonate (PC)	Polymethyl methacrylate (PMMA)
Tensile E modulus (ISO 527, cond.) [MPa]	2200	1600	2300	3200
Notched impact strength, Charpy 23°C (ISO 179/1eA, cond.) [kJ/m²]	8	13	no break	2
Glass transition temperature, DSC (ISO 11357, dry) [°C]	160	155	148	110
Heat deflection temperature HDT-B, 0.45 MPa (ISO 75, dry) [°C]	145	135	137	95
Transparency with 2 mm wall thickness (ASTM D-1003) [%]	93	94	90	94
Density (ISO 1183, dry) [g/cm³]	1.06	1.00	1.20	1.19
Fatigue strength (DIN 53442; 23°C) [MPa]	25	32	20	15

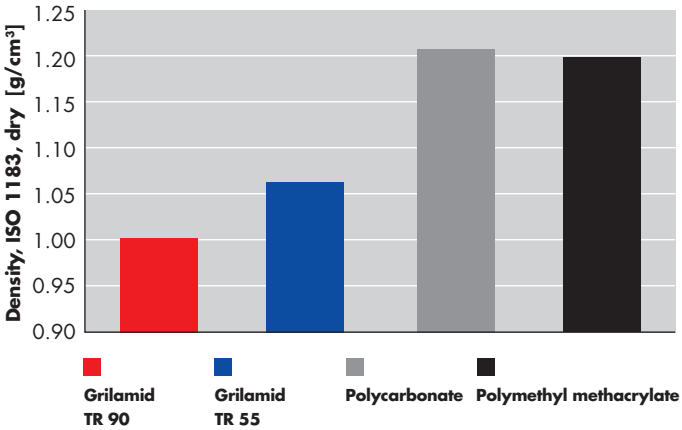
Transparency – a beauty to behold

The outstanding transparency of Grilamid TR allows it to be used in applications with the most stringent requirements for optical properties.



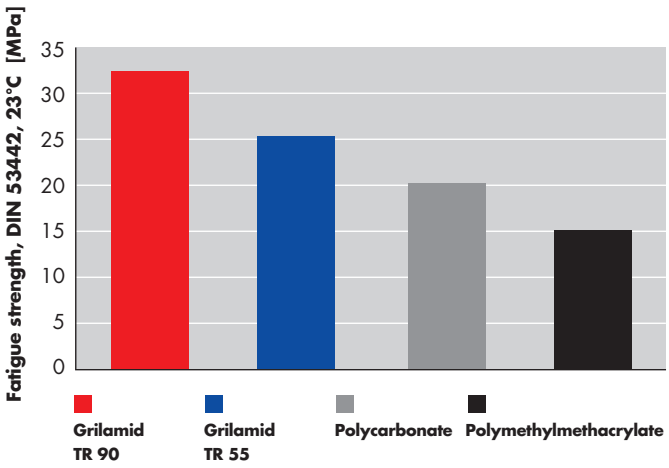
Density

Grilamid TR has a remarkably low density compared to other transparent polymers. It is the lightest engineering plastic in existence and therefore allows highly economical solutions to be developed. Its low weight is of extreme significance for use in the sports industry and in optics as well as for applications in automotive construction and the aviation industry.



Fatigue strength

Grilamid TR is characterised by its impressive dynamic loading capacity, which results in extremely high fatigue strength. This unique property allows the use of transparent polymers even in safety critical applications such as water filter housings in sanitary installations.

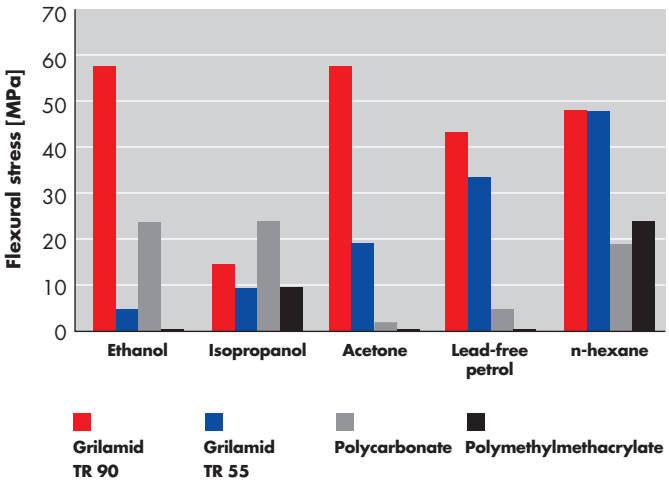


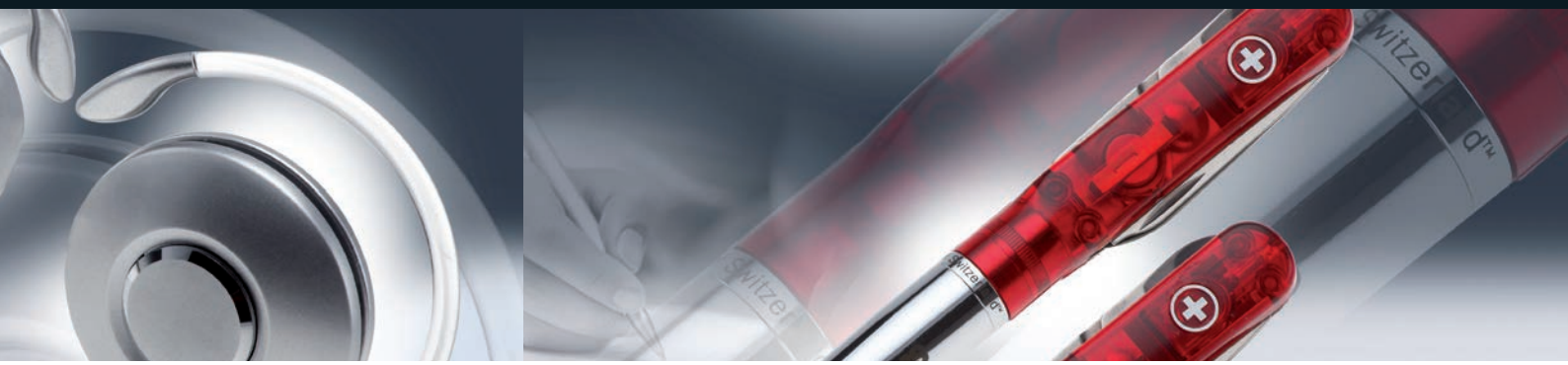
Resistance to stress cracking

The formation of stress cracks (also known as environmental stress cracking) is the most common cause of damage to plastic components and is particularly critical in the case of transparent plastic materials. It involves the formation of cracks due to the effects of contact media on plastic components under stress.
Thanks to its chemical structure, Grilamid TR exhibits excellent resistance to stress cracking compared with other transparent plastic materials in both polar media (e.g. ethanol, isopropanol) and non-polar media (e.g. petrol, hexane).

The resistance to stress cracking of transparent materials is tested using the bent strip method. The following diagram shows the values of flexural stress, in MPa, at which stress cracks are visibly apparent after one minute of contact with the liquid medium. Isolated incidents of clouding which occur are not recorded in the diagram.

In order to provide a clearer overview, only flexural stress up to 60 MPa is shown, although it may sometimes be considerably higher.





Grilamid TR nomenclature
Members of the Grilamid TR product family are amorphous polyamides which differ from one another due to their chemical structure. These are designated with numbers:

Grilamid TR 55
with a balanced property profile

Grilamid TR 90
with higher flexural fatigue strength and UV resistance

Building on these basic polymers, variants have been developed which offer additional properties. These are designated with letters:

LX	improved resistance to alcohol
LY	improved resistance to stress cracking
LZ	improved resistance to stress cracking + high strength
LS	easy demoulding
UV	resistant to weathering
NZ	very high impact strength
TRV	reinforced with fibres, maximum dimensional stability

Characteristics of Grilamid TR grades

Product	Characteristics												Typical applications
	Transparency	Heat deflection temperature	Stiffness / toughness	Impact strength	Dynamic strength	Resistance to chemicals	Resistance to stress cracking	Weatherability	Low warpage	Microcrystallinity	FDA / drinking water approval	Fibre reinforcement	
TR 55	●	●	●						●		●		Basic material with a high heat deflection temperature, good stiffness and toughness for transparent and non-warping applications such as observation windows, housings and cable sheathing for protection against rodent damage
TR 55 LX	●					●	●			●			For thin walled, transparent applications such as spectacle frames or housings with very good resistance to chemicals
TR 55 LY	●					●	●			●			Injection moulded parts with high demands on toughness and resistance to stress cracking
TR 55 LZ	●			●		●	●			●			For applications with the highest requirements on toughness and resistance to chemicals
TR 90 TR 90 LS	●	●			●			●	●		●		Basic material for applications requiring ductile breaking behaviour, dynamic loading and good weathering stability such as filter bowls and unbreakable spectacle frames
TR 90 UV	●	●			●			●	●				For outdoor applications with outstanding weathering stability
TR 90 LXS	●					●	●			●			For thin walled, transparent applications requiring very good resistance to stress cracking such as fine spectacle frames or housings
TR 90 NZ				●		●	●	●	●				Components with very high requirements on impact strength such as housings or safety glasses
TRV grades			●					●	●			●	Dimensionally stable and low warpage design components with consistent stiffness and strength values

	TR 55	TR 55 LX	TR 55 LY	TR 55 LZ	TR 90 / 90 LS	TR 90 UV	TR 90 LXS	TR 90 NZ	TRV grades	Special grades
Optics										
Spectacle frames for prescription glasses and sunglasses		●	●		●		●	●		
Frames for safety glasses				●				●		
Sun protective lenses / spectacle lenses										●
Electrical / electronics technology										
Electrical connectors	●				●					
IR sensor housings	●				●					
Mobile phone housings / components		●			●	●	●	●	●	
Telecommunication connectors		●	●							
Automotive construction										
Petrol filters		●	●							
Diesel / water separators	●									
Lubricant containers	●	●			●	●				
Remote controls, keyless locking systems	●				●				●	
Handles and holders					●	●		●	●	
Door mirror housings						●				
Interior housing components	●	●			●	●	●			
Industry										
Flowmeters	●				●					
Sight glasses / observation windows	●				●					
Petrol pump nozzle covers						●				
Lubricant containers	●				●					
Milking machine components	●				●					
Sanitary fittings										
Taps and brackets	●				●					
Valve housings / pressure reduction valves	●				●					
Water filter bowls					●					
Sight glasses	●				●					
Flowmeters	●				●					
Household appliances										
Coffee machine components	●				●					
Catering containers	●				●					
Vacuum containers / foodstuffs containers	●				●					
Sport / leisure										
Housings for diving computers						●				
Penknife handles		●			●		●			
Wristwatch cases					●		●			
Medical / personal protection										
Observation windows for protective masks	●				●					
Components for hearing aids and earphones		●					●			
Toothbrushes							●			
Personal search equipment					●	●		●		
Gas detector displays and housings	●				●					
Packaging										
Baby bottles	●				●					●
Cosmetics packaging					●		●			
Bottles for drinking water	●				●					

Properties

Mechanical properties				
Tensile E modulus	1 mm/min	ISO 527	MPa	cond.
Yield stress	50 mm/min	ISO 527	MPa	cond.
Yield strain	50 mm/min	ISO 527	%	cond.
Stress at break	50 mm/min	ISO 527	MPa	cond.
Strain at break	50 mm/min	ISO 527	%	cond.
Impact strength	Charpy, 23°C	ISO 179/2-1eU	kJ/m^2	cond.
Impact strength	Charpy, -30°C	ISO 179/2-1eU	kJ/m^2	cond.
Notched impact strength	Charpy, 23°C	ISO 179/2-1eA	kJ/m^2	cond.
Notched impact strength	Charpy, -30°C	ISO 179/2-1eA	kJ/m^2	cond.
Shore D hardness		ISO 868		cond.
Ball indentation hardness		ISO 2039-1	MPa	cond.
Thermal properties				
Glass transition temperature	DSC	ISO 11357	°C	dry
Heat deflection temperature HDT/A	1.80 MPa	ISO 75	°C	dry
Heat deflection temperature HDT/B	0.45 MPa	ISO 75	°C	dry
Heat deflection temperature HDT/C	8.00 MPa	ISO 75	°C	dry
Thermal expansion coefficient, long.	23–55°C	ISO 11359	$10^{-4}/K$	dry
Thermal expansion coefficient, trans.	23–55°C	ISO 11359	$10^{-4}/K$	dry
Max. working temperature	long-term	ISO 2578	°C	dry
Max. working temperature	short-term	ISO 2578	°C	dry
Electrical properties				
Dielectric strength		IEC 60243-1	kV/mm	cond.
Comparative tracking index	CTI	IEC 60112		cond.
Specific volume resistivity		IEC 60093	Ω · m	cond.
Specific surface resistivity		IEC 60093	Ω	cond.
General properties				
Transparency	2 mm	ASTM D-1003	%	dry
Density		ISO 1183	g/cm^3	dry
Flammability (UL 94)	0.8 mm	IEC 60695-11-10	Rating	
Water absorption	23°C/sat.	ISO 62	%	
Moisture absorption	23°C/50% r.h.	ISO 62	%	
Linear mould shrinkage	long.	ISO 294	%	dry
Linear mould shrinkage	trans.	ISO 294	%	dry
Product designation as per ISO 16396				

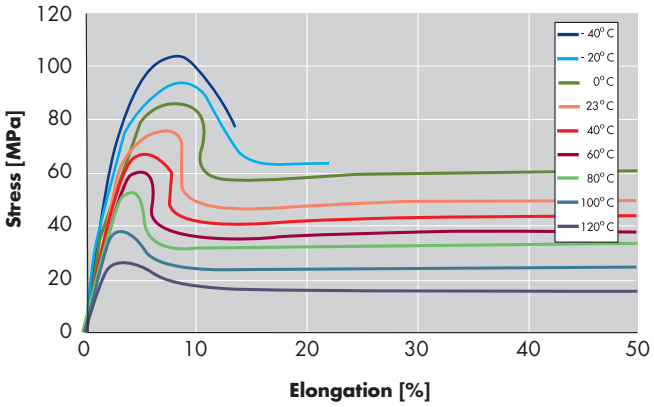
Grilamid TR 55	Grilamid TR 55 LX TR 55 LY	Grilamid TR 55 LZ	Grilamid TR 90 TR 90 LS	Grilamid TR 90 UV	Grilamid TR 90 NZ	Grilamid TR 90 LXS	Grilamid TRV-4X9	Grilamid TRVX-50X9	Grilamid TRV-55X9
2200	1900	1600	1600	1600	1300	1500	9000	12500	14000
75	70	55	60	60	50	60	-	-	-
9	6	6	6	6	7	6	-	-	-
50	40	40	45	45	45	45	130•	160•	165•
> 50	> 50	> 50	> 50	> 50	> 50	> 50	2•	2.1•	2.5•
no break	no break	no break	no break	no break	no break	no break	45	65	60
no break	no break	no break	no break	no break	no break	no break	45	60	55
8	9	20	13	10	22	9	14	16	15
7	8	8	12	9	15	12	13	15	14
85	82	77	82	82	73	80	87	87	89
120	110	90	90	90	90	85	160	190	200
160	110	110	155	155	155	125	155	125	130
130	80	75	115	115	110	80	135	115	125
145	90	85	135	135	135	100	-	-	-
-	-	-	-	-	-	-	125	105	115
0.80	0.90	1.10	0.90	0.90	0.90	0.90	0.20	0.20	0.10
0.80	0.90	1.10	0.90	0.90	0.90	0.90	0.80	0.80	0.80
80 –100	80	80	80 –100	80 –100	80 –100	80	80 –110	80 –110	80 –110
120	95	95	120	120	120	95	125	120	120
31	32	32	34	31	34	35	27	32	41
600	600	600	600	600	600	600	600	600	600
10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}	10^{11}
10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}
93	93	91	94	94	-	94	-	-	-
1.06	1.04	1.02	1.00	1.00	1.00	1.00	1.32	1.50	1.52
HB	HB	HB	HB	HB	HB	HB	HB	HB	HB
3.5	2.5	2.5	3.0	3.0	3.0	3.0	1.5	1.0	1.2
1.5	1.0	1.0	1.5	1.5	1.5	1.5	0.8	0.3	0.7
0.60	0.50	0.45	0.65	0.65	0.90	0.45	0.05	0.05	0.05
0.70	0.60	0.55	0.75	0.75	0.95	0.60	0.40	0.15	0.20
PA12/MACMI, GT, 11-020	PA12/ MACMI+PA12, GHLT, 14-020	PA12/MACMI +PA12-HI, GHLT, 12-020	PA MACM12, GT, 14-020	PA MACM12, GTL, 14-020	PA MACM12-HI, GHL, 14-020	PA12/MACM12 +PA12, GHLT, 18-020	PA MACM12, MGH, 14-090, GF40	PA MACM12+X, MH, 12-120, GF50	PA MACM12+X, MH, 12-140, GF55

• Testing speed 5 mm/min

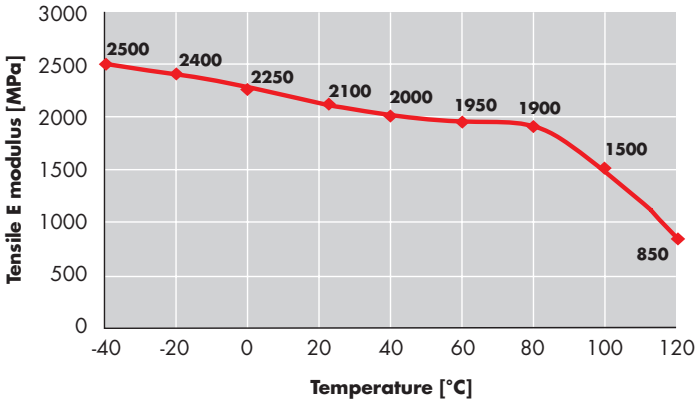
Design data – short-term behaviour

Mechanical properties as a function of temperature

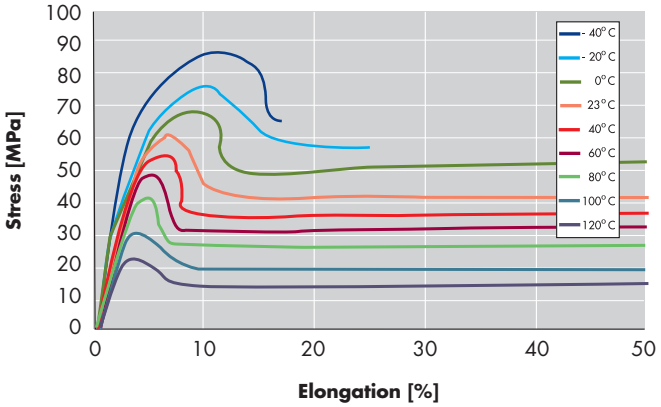
Tensile test Grilamid TR 55 conditioned



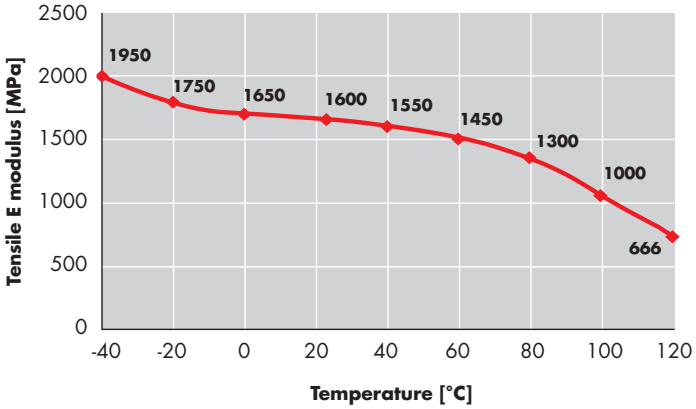
Tensile E modulus Grilamid TR 55 conditioned



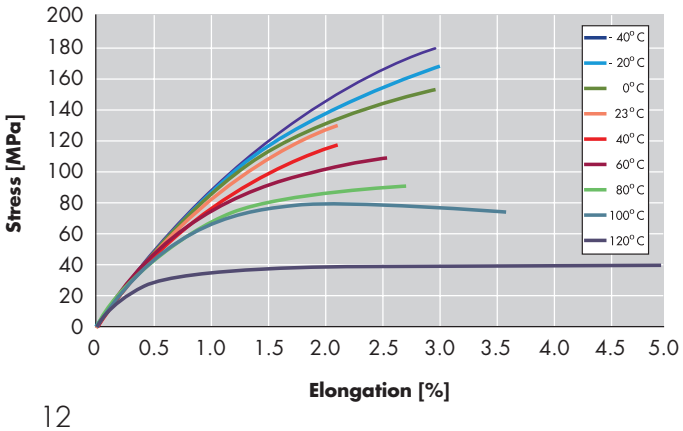
Tensile test Grilamid TR 90 conditioned



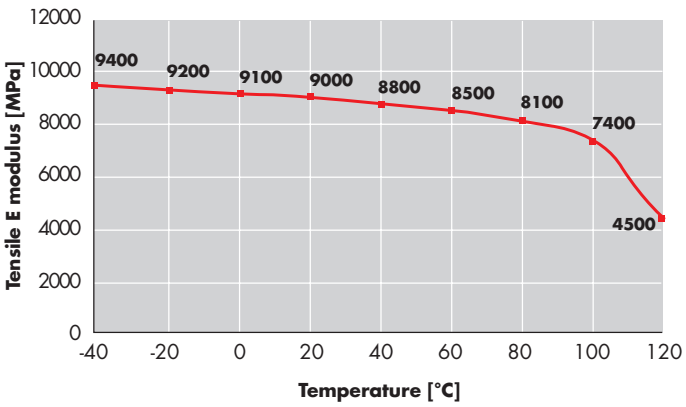
Tensile E modulus Grilamid TR 90 conditioned



Tensile test Grilamid TRV-4X9 conditioned

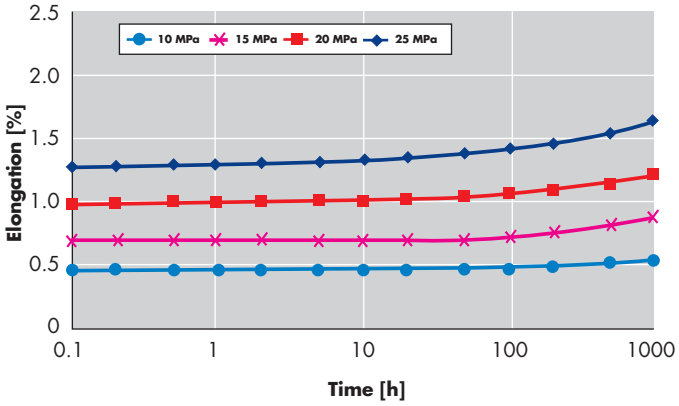


Tensile E modulus Grilamid TRV-4X9 conditioned

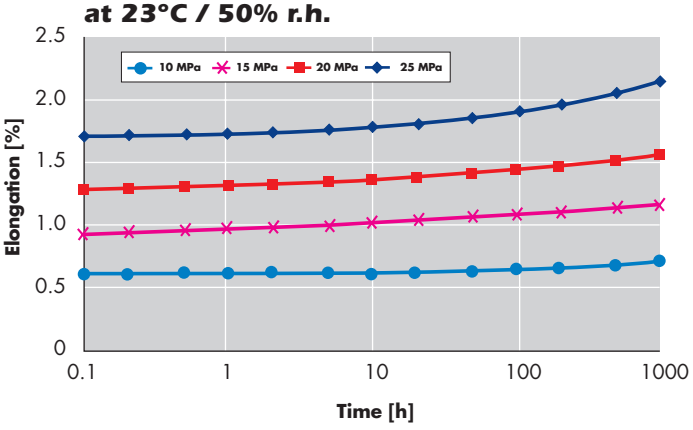


Following long-term static loading of a material under different mechanical stresses, characteristic creep curves for each plastic material can be plotted. The material "creeps" due to the effects of the loading and temperature.

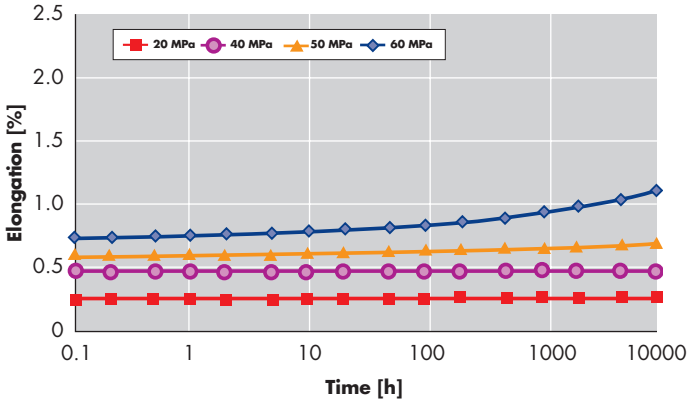
Creep curves for Grilamid TR 55 at 23°C / 50% r.h.



Creep curves for Grilamid TR 90 at 23°C / 50% r.h.

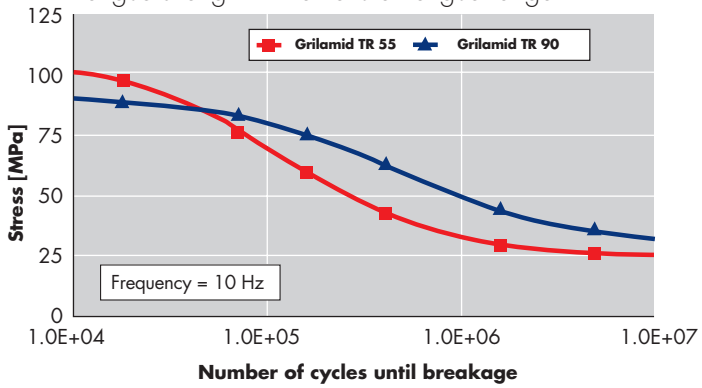


Creep curves for Grilamid TRV-4X9 at 23°C / 50% r.h.



Wöhler curves for Grilamid TR

Fatigue strength in the flexural fatigue range



Dynamic strength of Grilamid TR – flexural fatigue strength

Dynamic, long-term stress can lead to the failure of a thermoplastic material. Depending on the level of the cyclic mechanical stress, breakage occurs after a certain number of load cycles. The fatigue strength is shown here by the almost horizontal part of the Wöhler curve. This is the maximum load which a dynamically loaded material can withstand without any notable signs of fatigue.

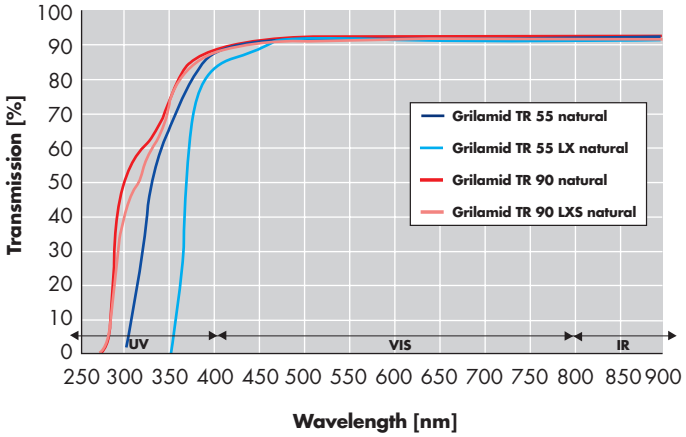
Grilamid TR 90 exhibits exceptionally good dynamic strength. The material has fatigue strength values in excess of 30 MPa, and even with flexural fatigue loading of ±50 MPa it still achieves one million flexural cycles (load changes). This means that Grilamid TR 90 is the preferred transparent plastic material for applications with stringent requirements for dynamic strength.

Optical properties

With its Grilamid TR product group, EMS-GRIVORY is the world market leader for polyamides in the field of spectacle frames and sun-protective lenses. Due to its excellent properties, including resistance to both chemicals and stress cracking as well as excellent optical and mechanical properties, Grilamid TR is suitable for a wide variety of uses in the optics industry.

Grilamid TR is extremely transparent, even with high wall thicknesses. With a wall thickness of 2 mm, its light-transmitting capacity (transmission) is approximately 94% in the visible light range.

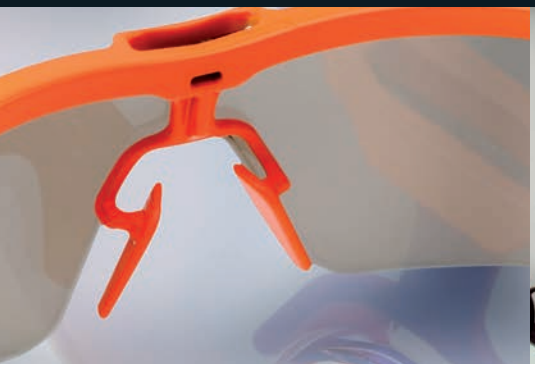
Light transmission of Grilamid TR
Specimen thickness 2 mm



Alongside the transmission value, the refractive index is one of the most important optical parameters. This plays a significant role in the design of optical devices for imaging optics, for example. The refractive index is the factor by which a ray of light is deflected when crossing from a vacuum into the relevant material.

The refractive index of various Grilamid TR materials is shown in the following table. The refractive indices n_D^{20} at 589 nm of Grilamid TR lie between 1.5 and 1.6.

Material	Refractive index n_D^{20} bei 589 nm
Grilamid TR 55 natural	1.539
Grilamid TR 55 LX natural	1.523
Grilamid TR 90 natural	1.510
Grilamid TR 90 LXS natural	1.511



Influencing factors
Within the group of materials known as engineering plastics, polyamides are characterised by their very good resistance to chemicals. Apart from concentrated acids, only a few chemicals affect polyamides. The chemical resistance of plastic materials is dependent on their molecular structure, the type and concentration of the chemicals (e.g. acids, bases, polar or non-polar solvents), temperature, the type and duration of contact.

Type and concentration of chemicals
A differentiation is made between physically active and chemically active chemicals. Physically active chemicals cause reversible changes such as swelling or softening. Chemically active chemicals change the material in an irreversible way. The material may be degraded by oxidation or other chemical reactions. In general, the extent to which the material is degraded is directly related to the concentration of the chemically active substance. The higher the concentration, the faster and more pronounced the degradation process of the material.

Temperature
The application temperature has a direct influence on a plastic's resistance to chemicals. The effect of chemicals on plastic materials is stronger and more rapid at higher temperatures.

Contact duration and type
In addition to the type of contact (1-sided, 2-sided, permanent and/or short-term), a plastic's resistance to chemicals is also affected by the contact duration (length of exposure). The longer the contact duration, the stronger the effect of the chemicals on the plastic.

Molecular structure of the plastic material
Grilamid TR belongs to the family of amorphous thermoplastics. Depending on the type, these have different molecular structures. This gives rise to characteristic differences in their resistance to chemicals. Grilamid TR materials exhibit high and, in some cases, very high resistance to chemicals. The comparison table on the following page shows the different behaviours of three Grilamid TR grades in contact with selected chemicals.

Testing
Tests to determine resistance to chemicals are carried out at room temperature and at selected application temperatures. A distinction is made between long-term exposure over a period of several weeks in a non-stressed condition and short-term exposure up to a maximum of one week in both a stressed and a non-stressed condition.

Characteristic property values such as changes in weight, length, volume, stress at break and strain at break are taken as testing criteria. A qualitative evaluation is given using the terms "resistant", "limited resistance" or "not resistant" and, in the following table, this evaluation refers to the test specimen in a non-stressed condition at the given testing temperature.

Long-term immersion in chemicals

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	Temperature	Grilamid TR 55	Grilamid TR 90	Grilamid TR 90 LXS
Formic acid (10%)	23°C	••	••	••
Battery acid (H_2SO_4 36%)	23°C	••	••	••
Petrol (super unleaded)	23°C 60°C	••• •••	••• ••	••• ••
Petrol, containing alcohol	23°C 60°C	o o	o o	o o
Brake fluid (DOT 4)	23°C 100°C	••• ••	••• •• *	••• •• *
Diesel fuel	23°C 60°C	••• •••	••• ••	••• •••
Descaling agent (amido sulphuric acid)	23°C 100°C/60h	••• ••	••• ••	••• ••
Acetic acid (10%)	23°C	•••	•••	•••
Ethanol	23°C	o	o	•••
Ethylene glycol / water 1:1 (coolant)	23°C 108°C	••• o	••• o	••• ••
n-hexane	23°C	•••	•••	•••
Potassium hydroxide (50%)	23°C	•••	•••	•••
Methanol	23°C	o	o	•••
Mineral oil (IRM 903)	23°C 100°C	••• •••	••• •••	••• •••
Hydrochloric acid (1%)	23°C	•••	•••	•••
Grease (mineral oil based and silicon oil based)	23°C 85°C	••• •••	••• •••	••• •••
Grease (synthetic)	23°C 85°C	••• ••	••• ••	••• ••

•••	**Resistant.** No or little change in weight or dimensions, no damage.
••	**Limited resistance.** Changes in weight or dimensions after longer periods, possibly irreversible changes of properties. We recommend contacting us before use.
o	**Not resistant.** May still sometimes be used under specific conditions (short exposure time, contact with droplets).

Tensile test specimens (ISO 527) immersed at 23°C were tested for mechanical properties after 5000 hours. Other specimens immersed at higher temperatures were tested after 3000 hours (unless stated otherwise).

* Slight yellowing.

Resistance of Grilamid TR products to stress cracking

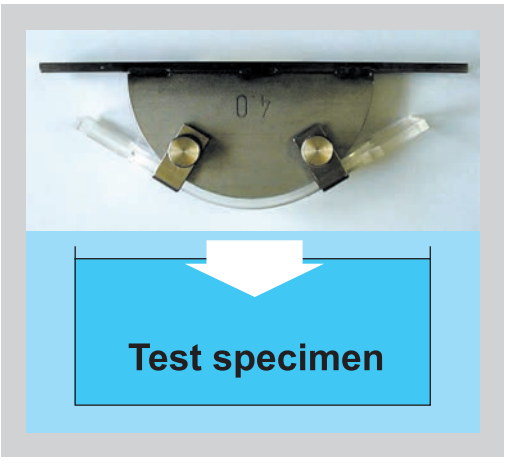
Despite the high chemical resistance exhibited by many transparent plastics, it is important to remember that these materials are prone to cracking when exposed to media and to internal and external stresses. This effect is called stress cracking. Statistically speaking, environmental stress cracking (ESC) is one of the most common causes of the failure of prefabricated components made of transparent plastics.
Stress cracking is defined as the result of the simultaneous effects of internal and external stresses and of surface-active media (e.g. solvents). Stress cracking is a physical process caused by the absorption of media and the resultant local swelling of the plastic. A characteristic feature of stress cracking is that it is limited to certain regions while other locations of the prefabricated component are unaffected.

There are many different test methods for determining stress cracking behaviour. The purpose of these tests is to demonstrate the effect of various media on plastics in conjunction with the influence of certain deformation or stress conditions. Many parameters have an influence on this effect, some examples being the duration of the test, the chemical medium or the surface quality.

At EMS-GRIVORY, testing of the resistance to stress cracking exhibited by Grilamid TR materials is carried out using the bent strip method (ISO 4599, DIN 53449). During this procedure, test specimens in a dry condition are fixed to rounded templates with a defined bending radius and then immersed in the test medium for one minute at room temperature. The different radii of curvature cause the outer surfaces to experience different amounts of radial elongation and, therefore, different amounts of flexural stress. The test specimens are then visually inspected for signs of stress cracking. The flexural stress at which the first stress cracks appear is recorded.

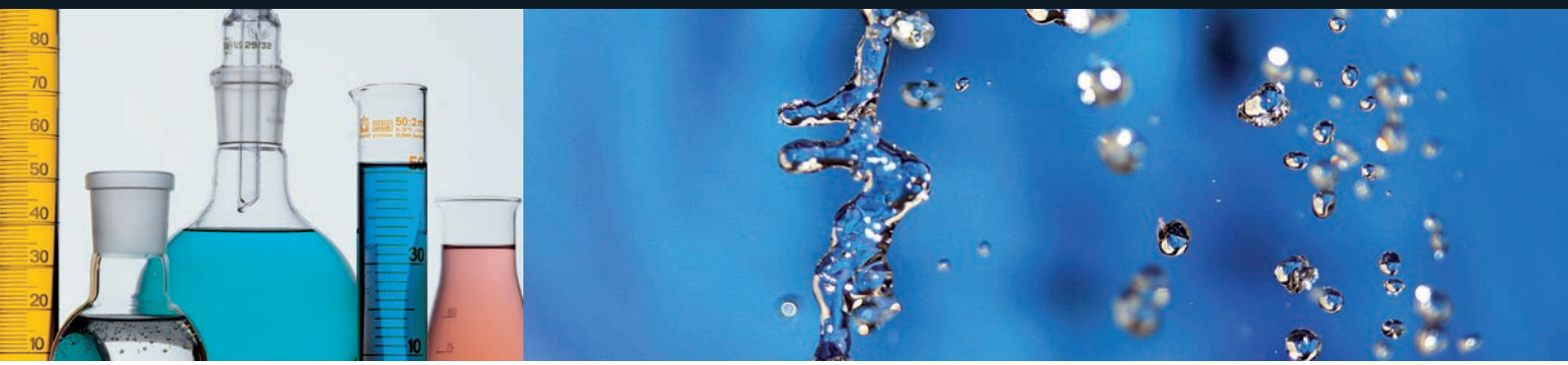
As a general rule, the higher the flexural stresses required to initiate stress cracking, the better the resistance of the plastic material to the test medium when immersed in it in the presence of external stress.

The following table shows the flexural stress (MPa) at which stress cracking first appears after a one-minute exposure to the chemical (test medium). Testing is carried out on dry test specimens using the bent strip method at 23°C.



Flexural stress [MPa]

Agent	Grilamid TR 55	Grilamid TR 90	Grilamid TR 90 LXS
Acetone	20	> 40	> 40
Petrol (FAM B)	30	> 40C	> 40
Petrol (ASTM Fuel C)	30	40	> 40
Butyl acetate	10	15	20
Cyclohexanone	20	15	> 40
Diesel	> 40	> 40	> 40
Dioctylphthalate	> 40	> 40	> 40
"Descaling agent" (amido sulphuric acid)	> 40	> 40	> 40
Ethanol	5	> 40C	> 40
Ethyl acetate	20	30	40
Ethyl ether	20	40	> 40
Ethyl methyl ketone	20	> 40	> 40
Isopropanol (100%)	10	15C	> 40
Isopropanol (80%)	20	> 40	> 40
Methoxypropyl acetate	20	15	15
Methyl isobutyl ketone	20	15	15
Mineral oil (IRM 903)	> 40	> 40	> 40
n-hexane	> 40	> 40	> 40
Nitro diluent	20	20	> 40
Petroleum ether 40 – 60°C	40	30	> 40
Peppermint oil	30	30	> 40
"Taski cleaning fluid R20 Strip F41" (10%)	> 40	> 40	> 40
Toluene	30	> 40	> 40
Xylene	30	> 40	> 40
C = clouding			



Water absorption

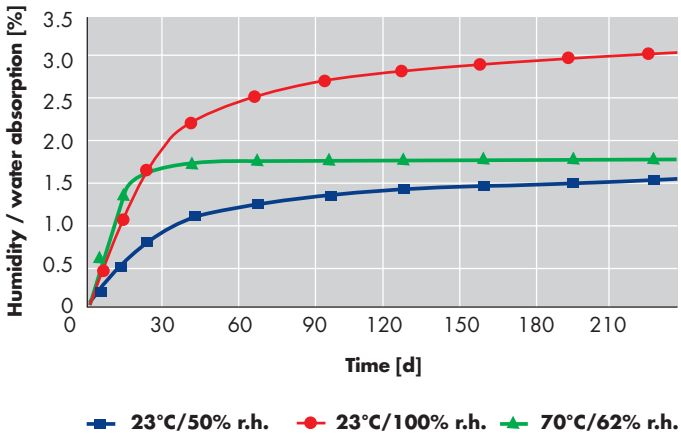
All polyamides react to ambient humidity by absorbing or releasing water. These processes are reversible and are largely determined by the amide group concentration of the relevant polyamide grade.
Compared to Polyamide 66, the Grilamid TR grades absorb much less water. Grilamid TR 55 and Grilamid TR 90 reach their saturation points at just 3.5% and 3.0%, respectively.

	TR 55	TR 55 LX	TR 90	TR 90 LXS
Water absorption 23°C/saturated	3.5	2.5	3.0	3.0
Moisture absorption 23°C/50% rel. humidity	1.5	1	1.5	1.5

Measured on plates (dimensions 100x100x3 mm)

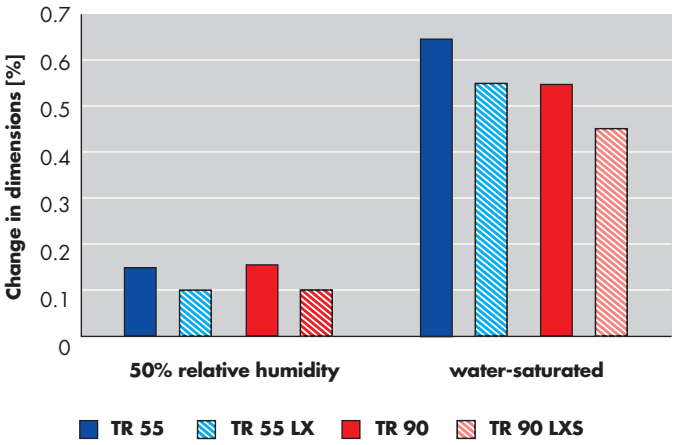
The speed of water absorption depends on ambient humidity and temperature.

Grilamid TR 90



It is notable that the mechanical properties are largely unaffected by water absorption.

The change in dimensions depends on the grade, e.g. in the case of Grilamid TR 90, the change is a maximum of 0.55%.

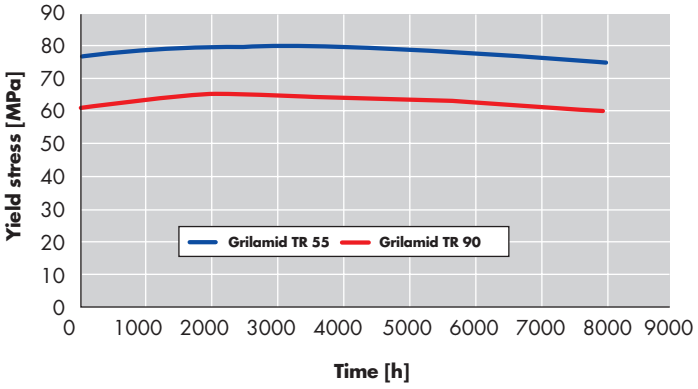


Resistance to hydrolysis / Suitability for sterilisation processes

Resistance to hydrolysis

Grilamid TR 55 and Grilamid TR 90 have good to very good resistance to hydrolysis in hot water. Cloudiness must be expected with Grilamid TR 90 after long periods of exposure to water at temperatures above 80°C (our experts will be happy to advise you). Evidence of the good resistance to hot water at 95°C exhibited by both Grilamid TR grades is provided in the following diagram. There is no significant change in the yield stress of Grilamid TR 55 and Grilamid TR 90 with a test duration of 8,000 hours.

Long-term behaviour in water at 95°C



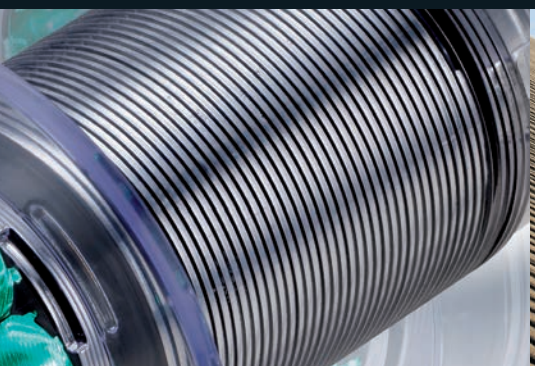
Suitability for sterilisation processes

All Grilamid TR grades are generally well suited to sterilisation. The table below shows a summary of conventional sterilisation methods and their effects on Grilamid TR. Tests were performed with tensile test specimens (ISO 527) with a low inherent stress condition. In the case of steam sterilisation, the resistance exhibited depends very much on the stress condition and orientation of the prefabricated component. In general, Grilamid TR 55 exhibits better resistance to steam than Grilamid TR 90.

	Grilamid TR 55	Grilamid TR 90
Steam 121°C, 1 bar, 30 min./cycle	••	••
Steam 134°C, 2 bar, 7 min./cycle	o	o
Gamma radiation (max. total dose 30 kGy = 3 Mrad)	•••	•••
Ethylene oxide gaseous	•••	•••

•••	Resistant. The material is suitable for several hundred sterilisation cycles.
••	Limited resistance. The material suffers damage after a time but can be sterilised several times.
o	Not resistant. The material quickly becomes cloudy, brittle or misshapen.

Resistance to weathering



Exposure to UV radiation causes changes in the chemical and physical properties of all plastics, including polyamides. In particular, a combination of radiation, oxygen in the air, humidity and temperature can lead to chain fission, crosslinking and other oxidative processes, resulting in a reduction of the material's working life.

Resistance to weathering is dependent on the polymer structure and type of reinforcement. The effects of weathering are observed mainly on the surface of the material so that the serviceability of a component is very dependent on its thickness.

The working life of polyamide components is determined using accelerated weathering tests (filtered xenon-arc light according to ISO 4892). Following this method, tensile testing specimens are subjected to artificial accelerated weathering in our materials testing department. The mechanical and optical properties of the specimens are measured after given periods of time.

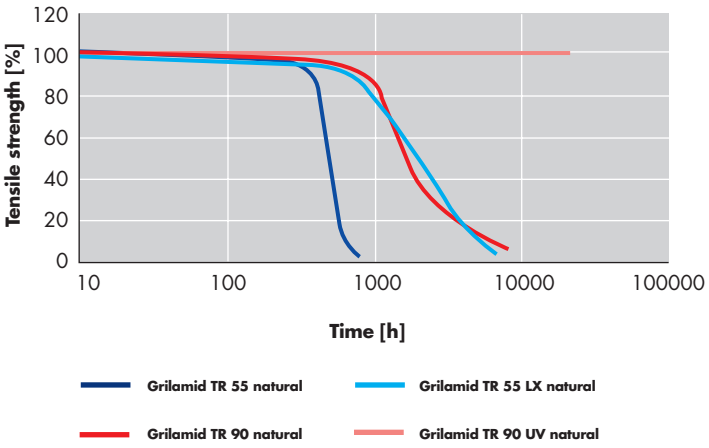
Grilamid TR exhibits generally high resistance to weathering. Grilamid TR 55 and Grilamid TR 90 UV are listed as f1 according to UL 746 C and are therefore suitable for outdoor applications.

Grilamid TR 90 is a highly transparent polyamide with excellent resistance to weathering and UV radiation.

Grilamid TR 90 UV was developed to produce a material which satisfies the most stringent requirements. The very good resistance to weathering exhibited by Grilamid TR 90, in combination with an optimised UV stabiliser system, results in a first-rate transparent product. Even after 20,000 hours of accelerated weathering (Florida test) at temperatures of 65°C, no noticeable change can be observed in the mechanical and optical properties (transparency, colour) of Grilamid TR 90 UV.

Grilamid TR 90 UV is thus the most weather resistant transparent polyamide available and is suitable for long-term outdoor applications even under the most extreme climatic conditions.

Tensile strength of Grilamid TR after weathering in accordance with ISO 4892-2



Test method: ISO 4892-2
Test specimen: ISO 294-2 3x3 mm

Approvals

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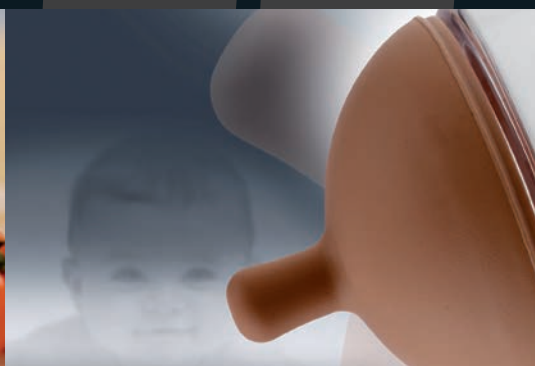


Grilamid TR in contact with foodstuffs

EU

In Directive 2002/72/EC and its supplements, the European Union has stipulated the conditions to be fulfilled by plastics in contact with foodstuffs.
Plastics may only be used in applications involving direct contact with foodstuffs when, alongside the monomers and other starting materials, any different additives they contain, such as lubrication agents, etc., are also approved for this kind of application.
The following Grilamid TR grades satisfy the EU guidelines for repeated direct contact with foodstuffs:

Grilamid TR 55 natural
Grilamid TR 90 natural
Grilamid TR 90 LS natural
Grilamid TR 90 LXS natural

Colour correction and lubricant masterbatches suitable for use with foodstuffs are also available.
It is essential that both global and specific migration of the monomers are tested on the end product. The suitability of Grilamid TR must be checked in relation to the foodstuff type and the temperature conditions. Please contact the responsible salesperson for more detailed information.

USA

Grilamid TR 55 natural is approved for repeated contact with foodstuffs with a maximum alcohol content of 8% according to FDA 21 CFR Section 177.1500 (11).
Grilamid TR 90 natural is approved for repeated contact with all types of foodstuffs according to Food Contact Notification 883 under conditions of use A to H.
Auxiliary substances, which are approved for use in polyamides in accordance with 21 CFR Section 177.1500, may be used in these polymers provided that the restrictions relating to conditions of use and foodstuff types are observed.

Grilamid TR in contact with drinking water
If taps and fittings are to be used in drinking water systems, the taps themselves and, in some cases, the material of which they are made, must be approved for use according to the regulations of the respective countries.

Germany (BGA, Federal Office of Public Health; DVGW, German Technical and Scientific Association for Gas and Water):
The following products have been tested according to the KTW (Plastics in Drinking Water) recommendations of the German Federal Office of Public Health and are approved for use in applications involving contact with hot drinking water (85°C) in Germany:

Grilamid TR 55 natural
Grilamid TR 90 natural
Grilamid TR 90 LS natural

The following products have passed the test according to the DVGW Code of Practice W270 "Microbial Enhancement on Materials to Come into Contact with Drinking Water – Testing and Assessment":

Grilamid TR 55 natural
Grilamid TR 55 natural 6504
Grilamid TR 90 natural
Grilamid TR 90 LS natural

UK (WRAS, Water Regulations Advisory Scheme):
The following products are approved for use in Great Britain according to WRAS in applications involving contact with hot drinking water (85°C):

Grilamid TR 55 natural
Grilamid TR 90 natural
Grilamid TR 90 LS natural

France (ACS, Attestation de Conformité Sanitaire):
The following products have been tested to ensure that their formulation complies with the French list of approved substances for contact with drinking water. If required, an ACS may be obtained for these products from one of the test institutes accredited by the French Ministry of Health:

Grilamid TR 55 natural
Grilamid TR 90 natural

USA (National Sanitation Foundation International):
NSF International tests materials for their suitability for use in drinking water applications in the USA.
The following Grilamid TR grades have been tested and certified as suitable for use in warm water (60°C) or hot water (82°C) applications, as per NSF/ANSI Standard 61 ("Drinking Water System Components – Health Effects"):

Grilamid TR 55 natural (60°C)
Grilamid TR 55 LX natural (60°C)
Grilamid TR 55 LY natural (60°C)
Grilamid TR 55 LZ natural (60°C)
Grilamid TR 90 natural (82°C)
Grilamid TRV-4X9 natural (82°C)

Grilamid TR for medicinal applications
Grilamid TR in contact with skin
Grilamid TR 55 LX natural and Grilamid TR 90 natural meet the requirements as per ISO 10993-5 (cytotoxicity) and ISO 10993-10 (tests for irritation and delayed-type hypersensitivity) for prolonged periods of skin contact.

Approvals for medicinal applications according to USP Class VI
The following products meet the requirements as per United States Pharmacopoeia, Class VI (USA):

Grilamid TR 55 natural
Grilamid TR 90 natural

Grilamid TR in the electric/ electronics industry

Underwriters Laboratories Inc. (UL) "yellow cards":
Grilamid TR 55 (all colours)
Grilamid TR 90 natural
Grilamid TR 90 UV natural
Grilamid TRV-55X9 (all colours)
Grilamid TRVX-50X9 (all colours)

Material preparation
Grilamid TR is delivered ready dried in sealed containers. Further drying before processing using injection-moulding methods is not necessary provided that the containers are undamaged and are stored correctly. However, pre-drying of Grilamid TR is an absolute necessity before use in all extrusion processes.

Storage
Amorphous polyamides can be stored for several years without any effect on the mechanical properties of the end product. When Grilamid TR products are being used in applications involving requirements for optimal colour or transparency, the storage period should not exceed 6 months and the storage temperature should be kept as low as possible. At temperatures exceeding 25°C, the oxidative saturation in the granules is accelerated as the temperature and the storage period increase. This only becomes apparent in the form of discolouration following thermal loading during the processing procedure.
Storage is recommended in a dry room in such a way that sacks are also protected from damage.

Handling and safety
Detailed information is provided in the "Material Safety Data Sheets" (MSDS) which are available on request when materials are ordered.

Drying damp granules
During the manufacturing process, Grilamid TR is dried to a water content of less than 0.08% and then packed. If packaging is damaged or if the material has been stored for too long in an open sack, the granules must be dried again before use. An excessively high water content may become apparent through foaming of the melt cake when purging or silvery streaks on the injection-moulded parts.

If additional drying is necessary, it can be carried out as follows:

Dry-air dryer:	
Temperature	max. 80°C
Time	4–8 hours
Dry-air dew point	- 40°C (at least -30°C)
Vacuum oven:	
Temperature	max. 100°C
Time	4–10 hours

Circulating air ovens are not suitable for Grilamid TR. In order to check or monitor the effective humidity content, we recommend using a suitable humidity meter.

Drying time
The minimum drying time is generally sufficient if there is only a small amount of foam in the melt cake or few silvery streaks on the injection-moulded part. If material has been stored open for days and there is a large amount of foam in the melt cake and an unusually thin and liquid melt, or there are pronounced streaks and a rough surface on the injection-moulded part, the maximum drying time is required.
Silvery streaks on the component can also be caused by overheating the melt (in excess of 330°C) or by excessively long dwell times in the cylinder.

Drying temperature
In a dry-air dryer, the maximum recommended temperature (80°C) must not be exceeded as this may cause yellowing due to oxidative damage. A higher temperature (100°C) is possible in a vacuum oven with a lower oxygen partial pressure. In order to ensure that yellowing can be identified in the case of light colours, we recommend holding back a small quantity of granules for comparison.

A hopper dryer with dry air (80°C) should be used where long dwell times with granules in the hopper (over 1 hour) are unavoidable.

Reusing reclaimed material
As a thermoplastic material, Grilamid TR allows reject parts runners and sprues to be prepared as reclaimed material. The partial re-feeding of reclaimed material into the injection moulding process is possible provided the following points are observed:

- no thermal damage during the previous processing steps
- no contamination by other materials, dust, oil, etc.
- the reclaimed material must be dry and free from dust

The person in charge of using reclaimed material must exercise particular care. Only new material should be used for engineered parts with high quality requirements.

Injection-moulding equipment
Grilamid TR can be processed using any injection-moulding equipment suitable for polyamides.

Screw
Wear-protected universal screws with a non-return valve are recommended (3 zones, length = 18 to 25 D, compression ratio = 2 to 2.5).

Charge volume
The screw diameter should be chosen to ensure that 50% – 80% of the maximum feed volume is utilised. The feed path (without the decompression path) must always be longer than the length of the non-return valve.

Heating
A minimum of three separately controlled heating zones should be capable of achieving cylinder temperatures of up to 350°C. A separate nozzle heating system is required. It must be possible to control the temperature of the cylinder flange (stock cooling, inflow).

Nozzle
Open nozzles with exact temperature control are preferable. However, there is a risk of air being drawn in during the screw return after metering (decompression). If shut-off nozzles are used, the frictional warming and pressure loss must be kept to a minimum. Longitudinal self-closing nozzles are not suitable.

Clamping pressure
As a guideline value, a clamping pressure of 7.5 kN per cm^2 of projected component area has proved suitable.

The standard guidelines applicable for all transparent thermoplastics are valid for the design of injection moulds.

Tool steel
Standard hard-wearing tool steels are sufficient for the moulding areas. Suitable types of steel are: 1.2767 (X45NiCrMo4), 1.2379 (X155CrVMo121), 1.2312 (40CrNMnMo58) and 1.2343 (X38CrMo V 51).

Venting
For Grilamid TR, vents (0.02 – 0.03 mm deep, 2 – 5 mm long) are important at the end of flow paths or at points of the mould where melt flows converge. Vents outside the parting planes must be provided by means of additional generously cut ejectors.

Sprue / gate system
A central sprue in the area of the greatest wall thickness is the best method of ensuring good filling of the mould and avoidance of sink marks. However, pinpoint gates (direct) or tunnel sprue systems are more economical and are often used even for engineered parts.

In order both to prevent premature freezing and to ensure easy mould filling, the following points should be observed:
- gate diameter: 0.8 x largest wall thickness
- sprue diameter: 1.4 x largest wall thickness of the injection-moulded part (but at least 4 mm)

Hot runner feed systems
The use of hot runner feed systems is also possible when processing Grilamid TR. We recommend externally heated and open systems.

Pressure absorber
The use of a pressure sensor inside the mould for precise control of the changeover point is recommended.

Demoulding

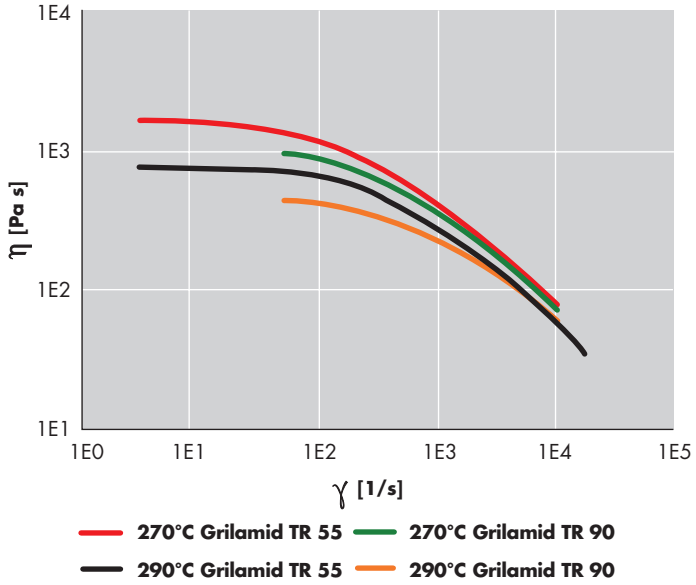
In general, an additional mould release agent is not required. Analogous products with a mould release agent are available for components with low demoulding draft angles or very long demoulding paths.

Experience has shown that special mould surface coatings, such as CNPTFE and Cr_2N, have also proved suitable for components with highly polished cores or small mould release draft angles.

Processing parameters

Temperatures	Tg [°C]	Feed [°C]	Melt [°C]	Mould [°C]
Grilamid TR 55	160	≥ 60	280–305	80–110
Grilamid TR 55 LX/ TR 55 LY/TR 55 LZ	110	≥ 40	250–270	40
Grilamid TR 90/ TR 90 LS/TR 90 UV	155	≥ 60	260–280	60–80
Grilamid TR 90 LXS	125	≥ 40	240–260	40
Grilamid TRV	155	≥ 60	270–290	80–120

Shear viscosity of Grilamid TR 55 and TR 90



Injection speed

The injection speed should be reduced towards the end of the filling cycle in order to avoid burning the material.

Hold pressure / Metering

- Hold pressure (specific): 400 – 600 bar
- Dynamic pressure (specific): 50 – 150 bar
- Screw peripheral speed: 0.1 – 0.3 m/s
  (metering time in relation to the residual cooling time)

Interruptions in production / Injection unit cleaning / Product change

- In the case of short interruptions in production (up to 1 hour), we recommend lowering the cylinder temperatures to 150°C without emptying the plasticising unit.
- In the event of longer interruptions in production, the system should be flushed with PA 12 or HDPE/PP, the plasticising unit emptied and the cylinder heating system should then be switched off.
- Grilamid TR is not compatible with other amorphous polymers such as polycarbonate or sulphone polymers. If the processing of Grilamid TR takes place following these materials, all traces must first be fully purged from the plasticising unit. Contamination which is difficult to remove (e.g. from sulphone polymers) can only be removed through mechanical cleaning of the screw, cylinder, non-return valve, nozzle head, etc.
- Unused Grilamid TR must be stored in a moisture-proof container or returned to a dry air dryer.

Injection blow moulding (IBM)
Injection unit temperatures: 250°C–290°C
Mould temperatures:

Mould			Pin
Neck	Body	Base	
90°C–110°C	130°C–150°C	110°C–130°C	130°C–160°C

Blow mould: 80°C–120°C

Blowing pressure: minimum 12 bar and maximum machine pressure

Injection-stretch blow moulding (ISBM, single stage)
Injection unit temperatures: 270°C–300°C
Injection mould temperatures:

Blow mould		Injection mould	
Base plate	Mould	Core	Mould
80°C–120°C	100°C–140°C	90°C–130°C	100°C–140°C

Blow mould:
with preform conditioning station (Nissei system):

- External heating: 230°C–300°C
- Core (oil): 120°C–190°C

Blowing pressure: Start with low pressure = 2 to 5 bar for at least 0.5 s, followed by pressure of up to 24 bar

IBM/ISBM – mould
For the hot runner system, we recommend externally heated, flat needle shut-off nozzles with precise temperature control.

Extruder
Grilamid TR can be successfully processed using extruders suitable for processing polyamides.

Screw
Three-zone screws with an L/D ratio ≥24 and a compression ratio of 2.5 – 3.5 : 1 have proved suitable. For higher outputs, it is also possible to use alternatives such as barrier screws.

Feed zone
We recommend the use of smooth feed bushes for the extrusion of Grilamid TR.

Processing parameters
The pre-drying of Grilamid TR is absolutely necessary when it is used in an extrusion processes.

Temperatures	Tg [°C]	Melt temperature [°C]	Head temperature [°C]
Grilamid TR 55	160	250–270	240–260
Grilamid TR 55 LX TR 55 LY/TR 55 LZ	110	250–270	240–260
Grilamid TR 90 TR 90 LS/TR 90 UV	155	240–260	230–250
Grilamid TR 90 LXS	125	240–260	230–250

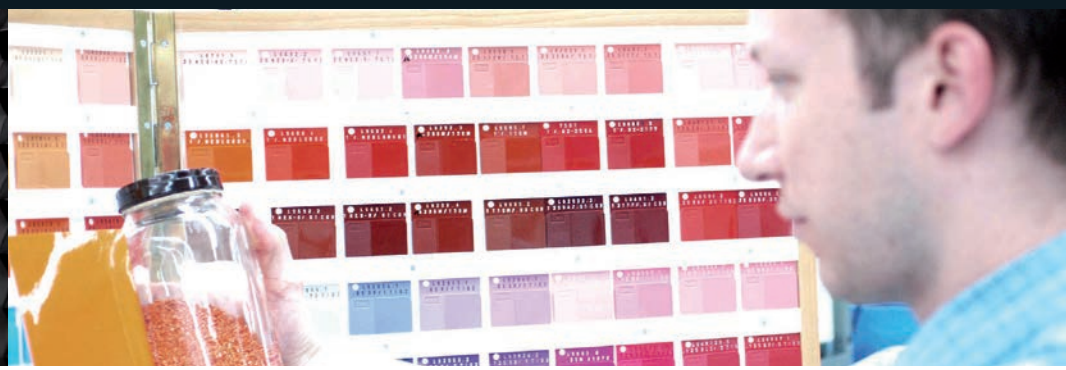
It is recommended that the hopper zone (feed) be maintained at a constant temperature of between 60 and 90°C.

For extrusion blow mould technology, a mould temperature of 60 to 80°C is recommended.

Post-treatment

Bonding technology

Adhesion	
General information / pre-treatment	Surfaces for adhesion should be clean and dry. The use of mould release agents is not recommended for the manufacture of parts which are to be glued. The joint strength can be enhanced by pre-treating the surfaces: - mechanical removal by brushing, grinding, sandblasting - electrochemical treatment through corona discharge, low-pressure plasma - thermal flame treatment - chemical treatment through the use of a primer; adhesive manufacturers offer suitable primer systems
Adhesives	Cyanacrylate adhesives, methacrylate adhesives: well suited for bonding Grilamid TR to metal; small bond areas with fine joints, very rapid setting Polyurethane adhesives: reactive single- or two-component adhesives as well as hot-melt adhesives; joint-filling pliable adhesives, often with a longer pot life and hardening time, suitable for adhesion over large areas. Epoxy resin adhesives: single- or two-component adhesives (joint-filling); longer pot life (hardening time); gap filling; large areas to be bonded
Welding	
	All welding methods developed for use with thermoplastics are suitable for welding Grilamid TR: - hot plate welding - ultrasonic welding with energy director or raised bead - friction welding: rotation or vibration - laser-beam welding
Screw fastening / Riveting / Beading	
	Injection-moulded parts made of Grilamid TR can be fastened with self-tapping screws. Metal threaded inserts can be inserted using ultrasonics. Riveting and staking is possible with ultrasound.
Injection welding	
	Following its compatibility with traditional welding methods, Grilamid TR can be bonded very successfully with the semi-crystalline Grilamid L and the flexible Grilflex grades using injection welding processes (multi-component injection moulding). Thermoplastic polyurethane elastomers (TPE-U) or bonding-modified styrene elastomers (TPE-S) are also suitable for use together with Grilamid TR in hard/soft combinations.

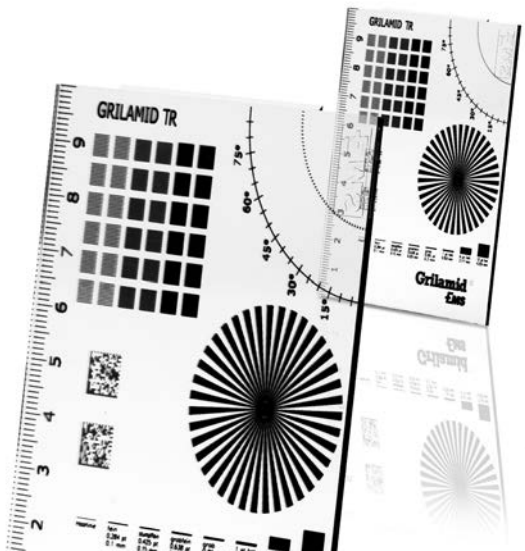


Printing and painting

General information / Pre-treatment	Surfaces to be printed should be clean and dry. The use of mould release agents is not recommended for the manufacture of parts which are to be printed or painted. Adhesion can be enhanced by pre-treating the surfaces by means of flame treatment, roughening or corona discharge / low-pressure plasma.
Paints	Two-component polyurethane paints have proved particularly well suited for painting Grilamid TR. Recommendations from and experience of the paint manufacturers should be taken into consideration when selecting the paints and solvents to be used.
Metal coating	Injection-moulded parts made of Grilamid TR can be metal-coated using conventional high-vacuum methods.
Dyes	Most dyes are approved for dye-sublimation printing. Screen-printing inks must be adapted for use with Grilamid TR.
Laser marking	Grilamid TR grades suitable for laser marking and printing are available.
Hot foil decoration	Hot foil decoration using compatible film can be applied to Grilamid TR without any problem.

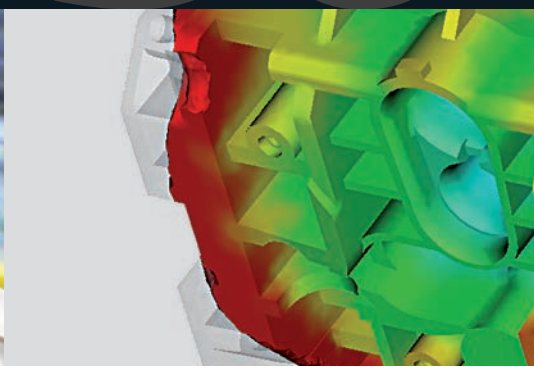
Mechanical post-treatment

Shaped parts/semi-finished products made of Grilamid TR can be machined by means of sawing, turning, drilling or milling; thermoforming can also be carried out. Additional cooling is recommended during mechanical processing in order to prevent the hot surfaces of the machined parts from sticking together.



Grilamid TR "with laser marking and lettering"

Service and technical support



We provide advisory services and know-how to our customers, starting from development and continuing right through to serial manufacture of a part. In this regard, we provide quality, reliability and extensive technical support.

- We draw up and discuss with you a range of designs for your applications in order to find an optimum solution from both a technical and an economic standpoint.

- As a material specialist, we will provide you with a material recommendation that "fits". We do this by comparing and analysing possible materials, thereby ensuring that we recommend the one best suited to your application.

- We also provide support in identifying and carrying out tests suited to your application. Our modern laboratories can offer a wide and varied range of mechanical, thermal, chemical and electrical tests.

- Are you experiencing problems with material sampling or the start of production? With our applications engineering know-how, we can offer you expert advice for processing and mould optimisation, and our Technical Customer Service department can also provide on-site support.

CAE

Using computer-aided engineering systems, EMS-GRIVORY application development centre are able to offer our customers a wide range of support services in this sector. CAE systems used include the Moldflow program modules FLOW, COOL and WARP for the simulation of injection moulding processes as well as the finite element (FE) programs NX-Nastron and ANSYS for mechanical part design and layout. Rheological simulation enables the optimum positioning of the gate to be determined before manufacturing of the mould is begun. These programs are also useful when changes to existing moulds are necessary because they provide an extremely efficient way of finding a solution. The variety of calculations which can be made ranges from simple flow pattern simulations, taking into consideration the influence of the cooling system, to qualitative statements about shrink behaviour and the warping of shaped parts. Part design using FE analysis provides information about highly stressed areas. This allows weak points in the design to be identified and corresponding modifications to be made. Through the use of both the NX-Nastron and CATIA 3D CAD systems, in combination with the Parasolid, IGES and STEP interfaces, EMS-GRIVORY is able to use the customer's own 3D CAD data directly as the basis for CAE simulations.

Prototypes

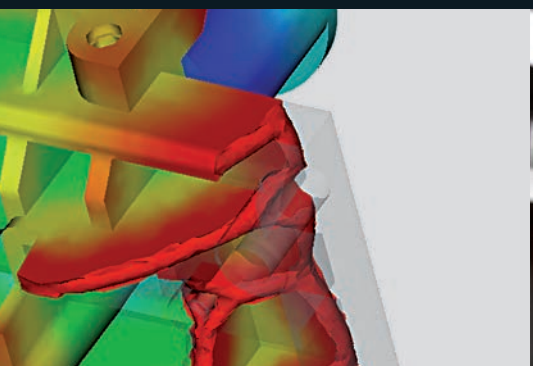
The key to success is the fast recognition and quick implementation of a good idea! EMS-GRIVORY helps to reduce the effort involved in the manufacture of prototypes, thereby saving valuable time and reducing costs.

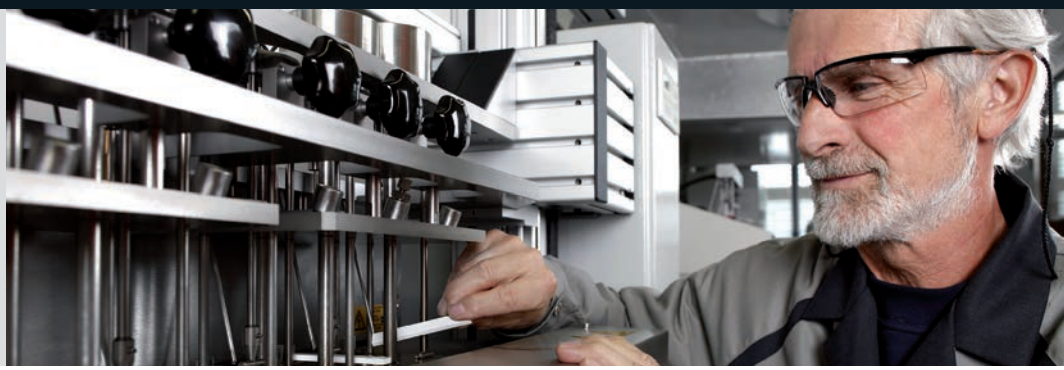
We can support you by manufacturing a small series of prototypes for the first practical tests.

In our application development centres, after small, reversible modifications we can also sample from metal die-casting moulds directly.

Within the shortest possible time, we therefore offer you the opportunity to test initial prototypes without the need to construct an injection mould in advance.

With these prototypes you can gain first practical experience and incorporate this knowledge into subsequent project phases, thereby eliminating the need to carry out expensive modifications to manufacturing moulds shortly before serial production.





Material testing and quality control
The EMS-GRIVORY Business Unit has at its disposal state-of-the-art, fully equipped laboratories for materials testing and quality control.

Our instrument infrastructure allows us not only to determine the standard mechanical, thermal and electrical properties of our materials for use in data sheets and approvals, but also to conduct research and development, applications engineering and provide practice-oriented support for our customers.

- Our mechanical test laboratory is equipped with modern tensile testing machines, automated and instrumented impact-testing equipment as well as test rigs to determine the creep behaviour of plastic materials in air and liquid media. We also have pneumatic flexural fatigue apparatus and a dynamic compression-tension machine available for testing the dynamic short and long-term loading behaviour of Grilamid TR materials.

- The rheological laboratory of our material testing department is capable of supplying characteristic property data for materials necessary for the simulation of the injection-moulding processes.

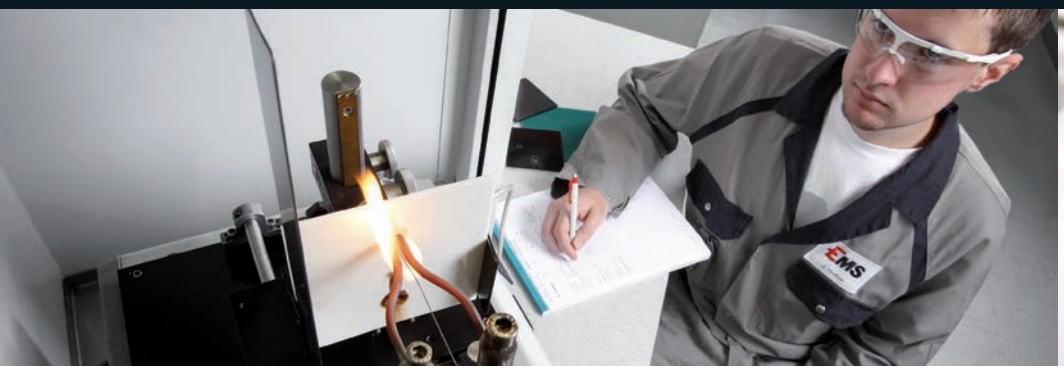
- Laboratory tests are carried out to examine the resistance to chemicals, heat and weathering provide important information about the use of our plastics in applications involving extreme conditions.

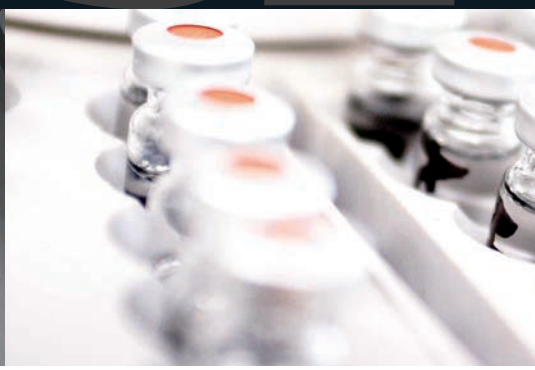
- Chemical and process-engineering tests ensure that the high quality levels of our products can be pro-perly monitored and consistent properties are guaranteed.

In addition, our materials testing department can make use of a variety of additional specialised equipment such as an EMS-P test unit (determination of the permeability of fuel-system components to petrol), a petrol circulation unit (testing of the working life of plastic petrol lines under extreme conditions), a hot air threshold pressure test (for practical testing of parts made using extrusion blow-moulding processes) and many more.

With these services, we offer our customers active support in the choice and development of materials as well as with component design and testing of finished parts.

CAMPUS





CAMPUS
stands for **C**omputer **A**ided **M**aterial **P**reselection by **U**niformed **S**tandards.

The database contains a careful selection of meaningful test results which accurately describe the property profile of a material. The specimens used to obtain these test results are produced under standardised injection-moulding conditions. Testing is carried out according to the international standards ISO 10350 and ISO 11403.

EMS-GRIVORY has taken an active part in the creation of the CAMPUS database since 1989. Currently, our testing laboratories have characterised more than 170 materials according to the CAMPUS profile regarding physical, chemical and process-engineering properties. These are shown in both tabular form (mechanical, thermal rheological and electrical property values) and graphical form (stress-strain, creep, shear/loss module, viscosity, pvT).

Material descriptions, information about resistance to chemicals, typical applications and processing information supplement the product profile.

The database programme and CAMPUS data can be downloaded from our website (www.emsgrivory.com).

The very comprehensive EMS Material Database is also available at the EMS-GRIVORY website. This facility not only enables you to quickly download technical and safety data sheets, also allows you to compare products directly, carry out a simple search by product designations or polymer groups, or conduct a more advanced search for specific properties, product features, applications or specific authority approvals.

All EMS-GRIVORY production sites throughout the world work in accordance with the same quality management system based on the ISO 9001:2008 and ISO/TS 16949:2009 standards. They are certified by the Swiss Association for Quality and Management Systems (Schweizerische Vereinigung für Qualitäts- und Management-Systeme, SQS). Compared to ISO 9001 which is found worldwide, ISO/TS 16949, which was developed by the automotive industry, contains further-reaching and more stringent requirements.

Our management system is process oriented. Our ultimate aim is customer satisfaction. Our efforts are concentrated on conformance with quality requirements and the appropriate use of resources.

The quality planning cycle begins with market research and ends with customer service. In the intermediate development phase, research and manufacturing face particular challenges.

Development projects are handled by inter-departmental teams working according to the principles of "simulta-neous engineering". Team members do not think and act solely within the confines of their own departments but instead strive to attain a common goal. Modern technology (such as statistical test design) and preventive methods (such as failure, probability and effect analysis) play a central role. The guiding principle of project management is "avoiding mistakes instead of correcting them".

Statistical process control is used for monitoring and improving our manufacturing processes. The accuracy of our inspection, measurment and test equipment is determined in controlled tests.

Continual improvement of products, services and productivity is the subject of official improvement programmes to which all of our employees are fully committed.

Our quality management system is primarily at the service of our customers, and our focus is based on their actual requirements and not on bureaucratic methods.

Delivery form

Grilamid TR is delivered as dry granules, packaged in moisture-proof sacks. Depending on the product, the sacks contain 20 or 25 kg. Pre-drying of material from unopened and undamaged sacks is not necessary.

Many Grilamid TR grades are available in natural or other colours. Special colours or deliveries in large containers are available on request. Our sales engineers will be happy to advise you further.

Recycling of packaging material
The disposal markings on our packaging material are criteria for sorting and guarantee type specific disposal.

In some European countries, EMS-GRIVORY pays disposal fees in advance, e.g. in cooperation with the RIGK scheme in Germany where empty packaging containers can be returned free of charge.

The recommendations and data given here are based on our experience to date. No liability can be assumed in connection with their usage and processing.

Please note: EMS-GRIVORY cannot assess any possible future health risks which could be caused by the long-term contact of our products with blood or tissue. For this reason, EMS-GRIVORY cannot promote medical applications involving long-term contact of plastic with blood or tissue.

Domat/Ems, October 2014

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EMS-GRIVORY worldwide
www.emsgrivory.com

EMS-GRIVORY - The leading manufacturer of high-performance polyamides
EMS-GRIVORY is the leading manufacturer of high-performance polyamides and the supplier with the widest range of polyamide materials. Our products are well-known throughout the world under the trade marks Grilamid, Grivory and Grilon.

We offer our customers a comprehensive package of high-capacity and high-quality products along with segment-specific advisory competence in distribution and application development. We maintain our market leadership through continual product and application development in all segments.

EMS-GRIVORY Europe

Switzerland
EMS-CHEMIE AG
Business Unit EMS-GRIVORY Europe
Via Innovativa 1
7013 Domat/Ems
Switzerland
Phone +41 81 632 78 88
Fax +41 81 632 76 65
welcome@emsgrivory.com

Germany
EMS-CHEMIE (Deutschland) Vertriebs GmbH
Warthweg 14
64823 Gross-Umstadt
Germany
Phone +49 6078 783 0
Fax +49 6078 783 416
welcome@de.emsgrivory.com

France
EMS-CHEMIE (France) S.A.
855 Avenue Roger Salengro
Boîte postale 16
92370 Chaville
France
Phone +33 1 41 10 06 10
Fax +33 1 48 25 56 07
welcome@fr.emsgrivory.com

Great Britain
EMS-CHEMIE (UK) Ltd.
Darfin House, Priestly Court
Staffordshire Technology Park
Stafford ST18 0LQ
Great Britain
Phone +44 1785 283 739
Fax +44 1785 283 722
welcome@uk.emsgrivory.com

Italy
EMS-CHEMIE (Italia) S.r.l.
Via Carloni 56
22100 Como (CO)
Italia
Tel. +39 011 0604522
Fax +39 011 0604522
welcome@it.emsgrivory.com

EMS-GRIVORY Asia

China
EMS-CHEMIE (China) Ltd.
227 Songbei Road
Suzhou Industrial Park
Suzhou City 215126
Jiangsu Province
P.R. China
Phone +86 512 8666 8180
Fax +86 512 8666 8210
welcome@cn.emsgrivory.com

EMS-CHEMIE (Suzhou) Ltd.
227 Songbei Road
Suzhou Industrial Park
Suzhou City 215126
Jiangsu Province
P.R. China
Phone +86 512 8666 8181
Fax +86 512 8666 8183
welcome@cn.emsgrivory.com

Taiwan
EMS-CHEMIE (Taiwan) Ltd.
36, Kwang Fu South Road
Hsin Chu Industrial Park
Fu Kou Hsiang
Hsin Chu Hsien 30351
Taiwan, R.O.C.
Phone +886 3 598 5335
Fax +886 3 598 5345
welcome@tw.emsgrivory.com

Korea
EMS-CHEMIE (Korea) Ltd.
#817 Doosan Venturedigm,
415 Heungan Daero,
Dongan-gu, Anyang-si,
Gyeonggi-do, 431-755
Republic of Korea
Phone +82 31 478 3159
Fax +82 31 478 3157
welcome@kr.emsgrivory.com

Japan
EMS-CHEMIE (Japan) Ltd.
EMS Building
2-11-20 Higashi-koujiya
Ota-ku, Tokyo 144-0033
Japan
Phone +81 3 5735 0611
Fax +81 3 5735 0614
welcome@jp.emsgrivory.com

EMS-GRIVORY America

United States
EMS-CHEMIE (North America) Inc.
2060 Corporate Way
P.O. Box 1717
Sumter, SC 29151
USA
Phone +1 803 481 61 71
Fax +1 803 481 61 21
welcome@us.emsgrivory.com

EMS-GRIVORY,
a business unit of the EMS Group

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