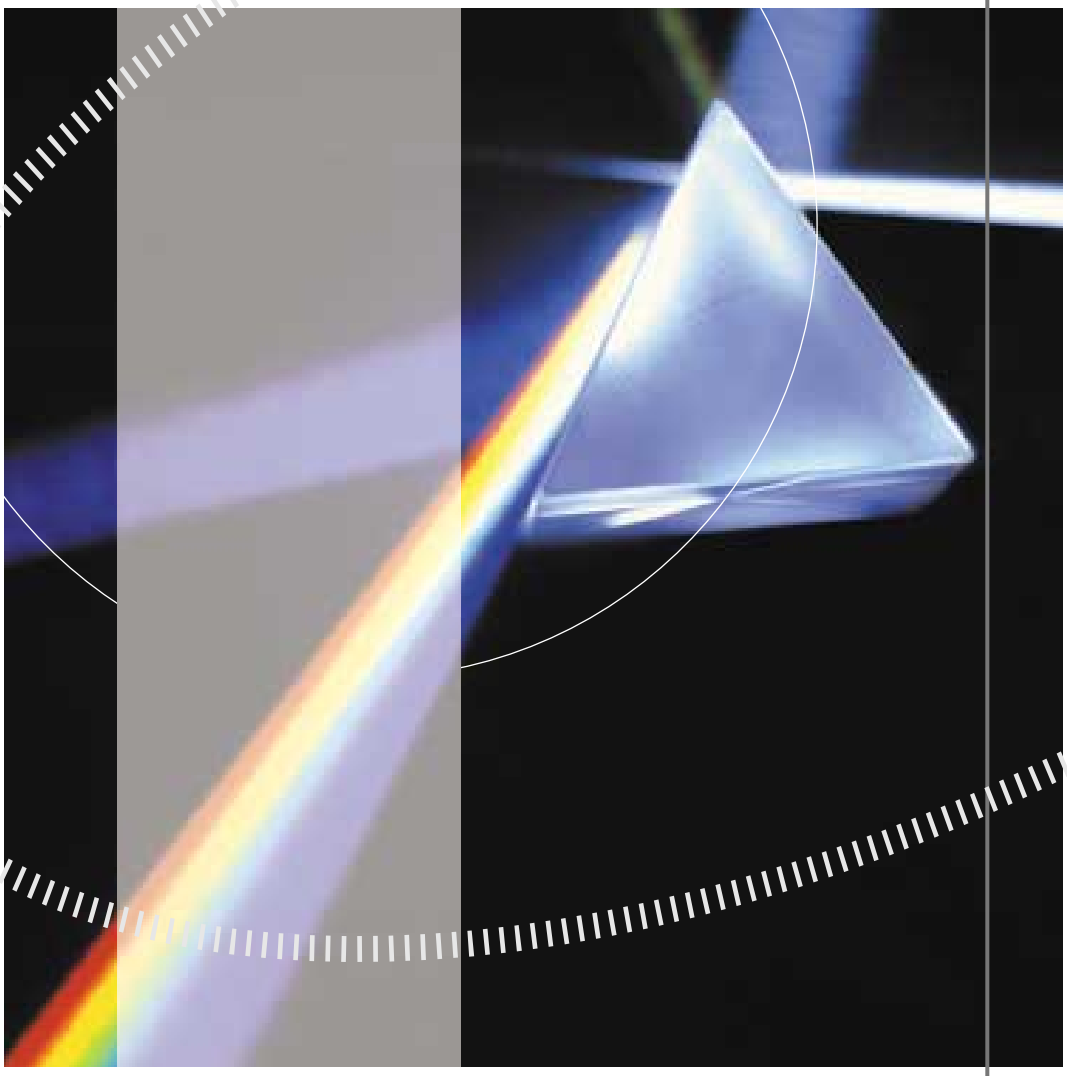

Grilamid TR

A transparent polyamide with unlimited possibilities

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Introduction

Grilamid TR is the brand name under which transparent polyamides manufactured by EMS-GRIVORY are marketed. These products are transparent polyamides which can be processed using thermoplastic methods and which are based on aliphatic, cyclo-aliphatic units which combine a range of various remarkable properties.

Grilamid TR belongs to the group of amorphous homo and copolyamides. Along with these transparent plastics, EMS-GRIVORY also manufactures and sells the thermoplastic materials Grilamid (polyamide 12), Grivory (partially aromatic polyamide) and Grilon (polyamide 6 and 66).

The exceptional property profile of Grilamid TR is very convincing:

- good transparency even at high wall thicknesses
- clear, light inherent colour
- resistant to chemicals and stress cracking
- high flexural fatigue strength
- toughness
- stiffness
- low flammability
- low water uptake
- easily colourable
- Grilamid TR does not contain plasticisers

Applications for the engineering thermoplastics Grilamid TR are well established in a variety of fields and range from everyday objects to technically demanding solutions.

Detailed knowledge concerning the behaviour of polyamides under the influence of mechanical and thermal stresses, exposure to weathering and chemicals, allow precise evaluation of application possibilities. In order to characterise the products comprehensively, a varies of tests and inspections are carried out, in close co-operation with customers, at the modern laboratories available within the EMS-GRIVORY facilities.

Property review - Comparison with other amorphous plastic materials

Grilamid TR grades are amorphous thermoplastics which, due to their composition, combine in a unique manner the good properties of semi-crystalline polyamide 12 grades with those of amorphous thermoplastics.

One particularly outstanding property of these materials is their high resistance to chemicals and stress cracking combined with the excellent transparency of amorphous plastics. This combination makes applications possible, where traditional transparent engineering plastics are limited due to their tendency to stress crack when in contact with certain media.

The excellent flexural fatigue strength of Grilamid TR 90 is another important property which opens up application possibilities involving dynamic stressing.

The transparency, rigidity and impact strength of Grilamid TR products compare favourably to those of other traditional transparent polymers. One major feature of Grilamid TR grades is its low specific density, up to 20% lower than that of polycarbonate.

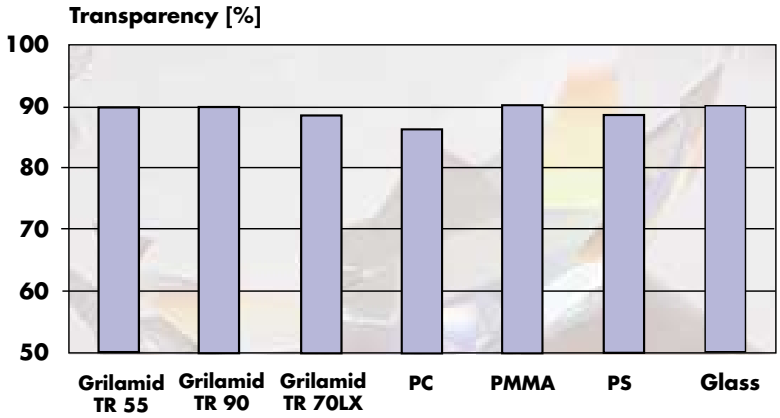
Comparison of properties

Property	**Grilamid TR 55**	**Grilamid TR 90**	**Grilamid TR 70 LX**
Transparency 550nm, 3 mm [%]	90	90	89
Glass transition temperature, DSC (ISO 11357, dry) [°C]	160	155	190
E-modulus (ISO 527, cond.) [MPa]	2200	1600	2300
Notched impact strength Charpy 23°C (ISO 179/1eA, cond.) [kJ/m^2]	8	13	6
Heat distortion temperature, HDT-B 0.45 MPa (ISO 75, dry) [°C]	145	135	165
Density (ISO 1183, dry) [g/cm^3]	1.06	1.00	1.05

Property	**Polycarbonate (PC)**	**Polymethyl methacrylate (PMMA)**	**Polystyrene (PS)**
Transparency 550nm, 3 mm [%]	87	91	89
Glass transition temperature, DSC (ISO 11357, dry) [°C]	148	110	100
E-modulus (ISO 527, cond.) [MPa]	2300	3200	3300
Notched impact strength Charpy 23°C (ISO 179/1eA, cond.) [kJ/m^2]	no break	2	3
Heat distortion temperature, HDT-B 0.45 MPa (ISO 75, dry) [°C]	137	95	85
Density (ISO 1183, dry) [g/cm^3]	1.20	1.19	1.05

Transparency - beauty to behold

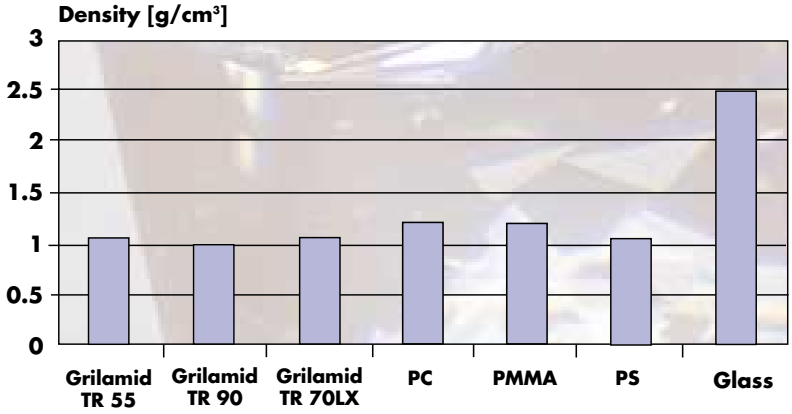
The limpid transparency of Grilamid TR - similar to that of glass - allows it to be used in applications with stringent requirements for optical properties.



Transparency at 550 nm, 3 mm wall thickness

High Performance – low weight

Compared to other transparent construction materials, Grilamid TR has a noticeably low density. It is the lightest engineering plastic in existence and, therefore, allows very economical solutions to be developed. The low weight is of extreme significance for applications in automotive construction and the aviation industry offering energy saving opportunities.



Density as per ISO 1183, dry

In the sport and optical industries, this low weight characteristic contributes toward ease of handling of articles made from Grilamid TR and also to wearer comfort.

Grilamid TR's high-performance property profile combined with its very good processability makes this material an attractive and precious engineering plastic.

Grilamid TR nomenclature

Type of polyamide

TR:	transparent
TR 55:	Basic grade with a balanced property profile
TR 70:	high glass transition temperature
TR 90:	extremely high dynamic strength
TRV:	reinforced with glass fibres

Special additives, properties

LS:	improved flow properties
LX:	tough, resistant to stress cracking
LY:	impact resistant, resistant to stress cracking
LZ:	extremely impact resistant, resistant to stress cracking
UV:	resistant to weathering

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Characteristics and typical application areas for Grilamid TR grades

Product	Characteristics	Typical application examples
TR 55	• High transparency, even in thick-walled components • Clear, light inherent colour • High heat distortion temperature • Combination of stiffness and toughness • FDA listed • High tenacity	Injection-moulding applications such as: viewing glasses, different transparent housings - also for foodstuff applications. Extruded cable sheathing providing protection against rodent damage.
TR 55 LX	• High transparency • Very resistant to chemicals • Increased resistance to stress cracking • Very good processing characteristics (flowability in injection moulding) • Good resistance to weathering • High impact strength	Injection-moulding grade for high-quality spectacle frames, hearing aids, transparent housings exposed to chemicals
TR 55 LY	• High transparency • Very high resistance to chemicals • Increased resistance to stress cracking • Good resistance to weathering • High impact strength	Grade for transparent injection-moulded parts requiring toughness and resistance to stress cracking
TR 55 LZ	• Excellent impact strength • Transparent • Very good resistance to chemicals and stress cracking	Transparent injection-moulding applications with very high requirements for impact strength and resistance to chemicals
TR 55 LX2	• Good resistance to chemicals • Low thermal expansion • Low post-shrinkage and extrusion shrinkage • Excellent resistance to lateral pressure • Excellent creep strength	Extrusion applications, e.g. single-layer loose-jacket cable sheathing for optical fibres
TR 90	• Very high transparency • Excellent dynamic strength • Very good resistance to chemicals • Very good resistance to stress cracking • Very good toughness • Good resistance to weathering • Very low density	Injection-moulded parts under dynamic stressing with excellent transparency and resistance to stress cracking, such as filter bowls. In optics: unbreakable, filigree spectacles frames
TR 90 LS	• Similar property profile to that of TR 90 • Very good flow characteristics	Injection moulding applications requiring easy flow and having long flow paths or long cores.
TR 90 UV	• Similar property profile to that of TR 90 • Extremely high resistance to weathering	Injection-moulded parts with stringent requirements regarding weathering resistance in long-term external applications.
TR 90 LX	• High transparency • Good resistance to chemicals and stress cracking • Good toughness • Very good flow characteristics for injection moulding	Thin-walled, transparent injection-moulded articles with very good resistance to stress cracking
TR 70 LX	• Transparent • Very high heat distortion temperature • Good resistance to scratching • Resistant to chemicals and stress cracking • Good stiffness • Pharmacopeia approval as per USP 23 class VI	Injection-moulding applications requiring transparency, resistance to chemicals and high heat distortion temp. e.g. medicinal apparatus or parts in contact with hot oil.
TRV-4X9	• Reinforced with glass fibres • Contact transparency • Heat and UV stabilised • Very good stiffness and heat distortion temperature • Good dimensional stability	Injection-moulding grade for dimensionally stable design components.

Application examples

Optic

Examples	Suitable grades
Frames for safety glasses	TR 55 LY, TR 55 LZ
Lens / optical glasses	Special grades available on request.
Mask window for breathing apparatus	TR 55
Spectacles frames, corrective glasses and sport sun glasses	TR 55 LX, TR 90, TR 90 LX

Electro/Electronic

Anti-rodent protective cable sheathing	TR 55, TR 55 LX2
Electrical plugs	TR 55
IR sensor housing	TR 55, TR 90
Light beam cover	TR 55
Mobile 'phone housing	TR 55 LX, TR 90 UV
Optical fibre / single-fibre loose jacket	TR 55
Parts for hearing aids and earphones	TR 55 LX, TR 55 LY
Telecommunication connectors	TR 55 LY

Automotive construction

Diesel / water separator	TR 55
Display components, instrument panel	TR 90
Handles and holders	TR 90
Housing components	TR 90
Oil and fat containers	TR 55
Petrol filter	TR 55 LX, TR 55 LY
Remote controls, keyless locking systems	TR 55, TR 90
Wing mirror / wing mirror housing in bodywork colour	TR 90 UV

Industry

Examples	Suitable grades
Flow meter	TR 55, TR 90 LS
Medicinal articles and apparatus	TR 70 LX
Milking-machine housings / components	TR 90, TR 55
Sanitary fittings and holders	TR 55, TR 90
Sight glasses, displays and covers at petrol stations	TR 90 UV
Sight glasses / windows	TR 55, TR 90, TR 90 UV
Transparent housing components for household and catering appliances	TR 55, TR 90
Valves for beverage machines	TRV-4X9
Valve housings / pressure reduction valves	TR 90
Water filter bowls, filter covers, pneumatic air bowls	TR 90, TR 90 LS
Water pressure gauges	TR 55

Sport & Leisure time

Diving fins, diving equipment	TR 90
Penknife grip section	TR 90 LX
Toothbrushes	TR 55 LX, TR 90 LX
Transparent zip fasteners	TR 90, TR 90 LX, TR 55 LX
Wristwatches	TR 90

Packaging

Baby bottles	TR 55, TR 90
Catering containers	TR 55
Cosmetic packagings	TR 90

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Properties

Mechanical properties				
Tensile E-modulus	1 mm/min	ISO 527	MPa	cond.
Tensile strength at yield	50 mm/min	ISO 527	MPa	cond.
Elongation at yield	50 mm/min	ISO 527	%	cond.
Tensile strength at break	50 mm/min	ISO 527	MPa	cond.
Elongation 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 76	°C	dry
Therm. expansion coefficient long.	23 - 55°C	ISO 11359	$10^{-4}/K$	dry
Therm. 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.
Volume resistivity		IEC 60093	Ω m	cond.
Surface resistivity		IEC 60093	Ω	cond.
General properties				
Density		ISO 1183	g/cm^3	dry
Flammability (UL94)	0.8 mm	ISO 1210	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
Nomenclature as per ISO 1874				

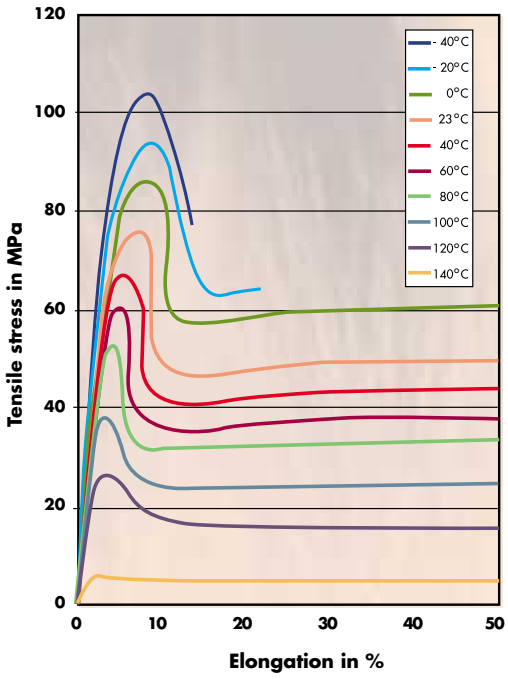
• Testing speed 5 mm/min

Grilamid TR 55	Grilamid TR 55 LX	Grilamid TR 55 LX 2	Grilamid TR 55 LY	Grilamid TR 55 LZ	Grilamid TR 90 TR 90 LS	Grilamid TR 90 UV	Grilamid TR 90 LX	Grilamid TR 70 LX	Grilamid TRV-4X9
2200	1900	1800	1900	1600	1600	1600	1500	2300	9000
75	70	70	70	55	60	60	60	75	*
9	6	7	6	6	6	6	6	6	*
50	40	45	40	40	45	45	45	55	130 •
> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50	2 •
no break	no break	no break	no break	no break	no break	no break	no break	no break	45
no break	no break	no break	no break	no break	no break	no break	no break	no break	45
8	9	8	9	20	13	10	9	6	14
7	8	7	8	8	12	9	12	4	13
85	82	80	82	77	82	82	80	85	87
120	110	105	110	90	90	90	85	125	160
160	110	110	110	110	155	155	125	190	155
130	80	60	80	75	115	115	80	150	135
145	90	75	90	85	135	135	100	165	*
*	*	*	*	*	*	*	*	*	125
0.80	0.90	1.10	0.90	1.10	0.90	0.90	0.90	0.80	0.20
0.80	0.90	1.10	0.90	1.10	0.90	0.90	0.90	0.80	0.80
80 - 100	80	80	80	80	80 - 100	80 - 100	80	80 - 100	80 - 110
120	95	95	95	95	120	120	95	140	125
31	32	32	32	32	34	31	35	32	27
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}
1.06	1.04	1.03	1.04	1.02	1.00	1.00	1.00	1.02	1.32
HB	HB	HB	HB	HB	HB	HB	HB	V2	HB
3.5	2.5	2.5	2.5	2.5	3.0	3.0	3.0	4.0	1.5
1.5	1.0	1.0	1.0	1.0	1.5	1.5	1.5	2.0	0.8
0.60	0.50	0.50	0.35	0.45	0.65	0.65	0.45	0.85	0.05
0.70	0.60	0.60	0.45	0.55	0.75	0.75	0.60	0.95	0.40
PA12/MACMI, GT, 11-020	PA12/MACMI+PA12, GHLT, 14-020	PA12/MACMI+PA12, GHLT, 14-020	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,+PA12, GHLT, 18-020	PA MACMI/12+PA MACM12, GHT, 11-020	PA MACM12, MGH, 14-090, GF40

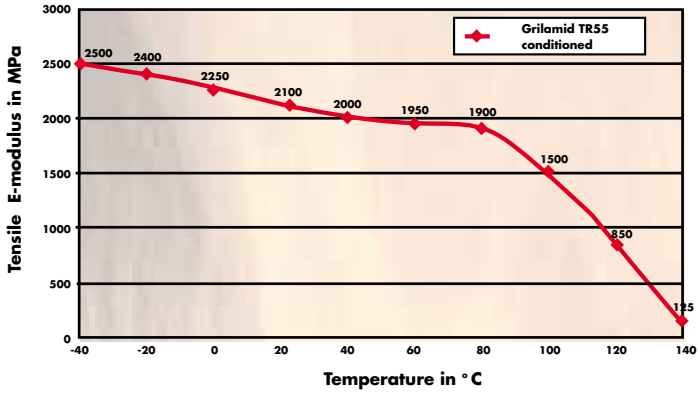
Design data - short-term behaviour

Mechanical properties as a function of temperature

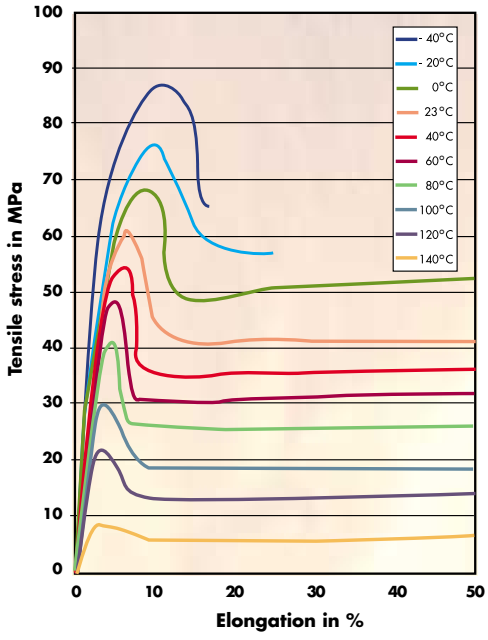
Tensile test Grilamid TR55 - conditioned



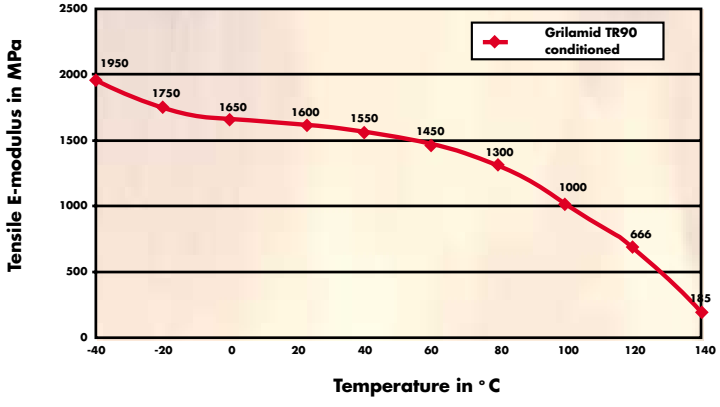
Tensile E-modulus Grilamid TR55 - conditioned



Tensile test Grilamid TR90 - conditioned



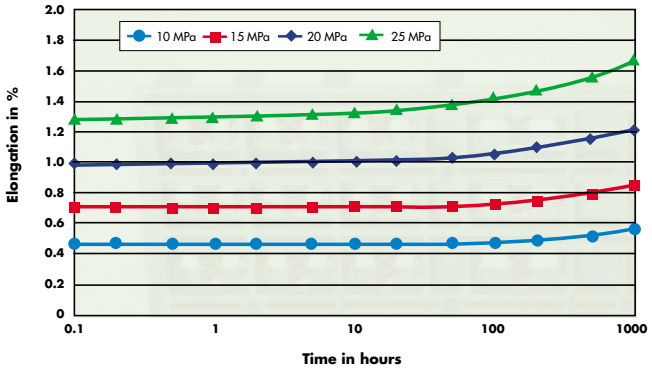
Tensile E-modulus Grilamid TR90 - conditioned



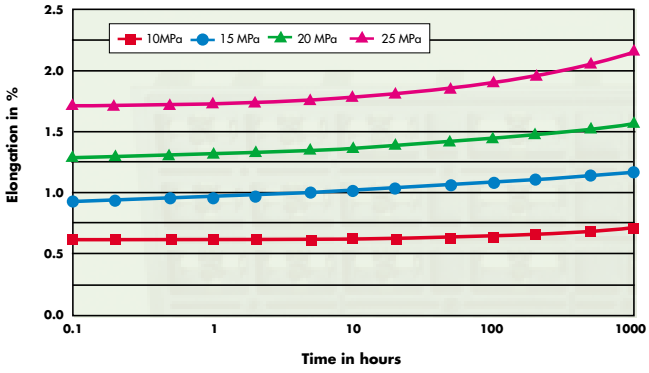
Design data - long-term behaviour

Following long-term static stressing of construction materials under different mechanical loads, characteristic time-elongation curves for each plastic material can be plotted. The material "creeps" due to the effects of stress and temperature.

Creep curves for Grilamid TR55 at 23°C / 50 % r.h.



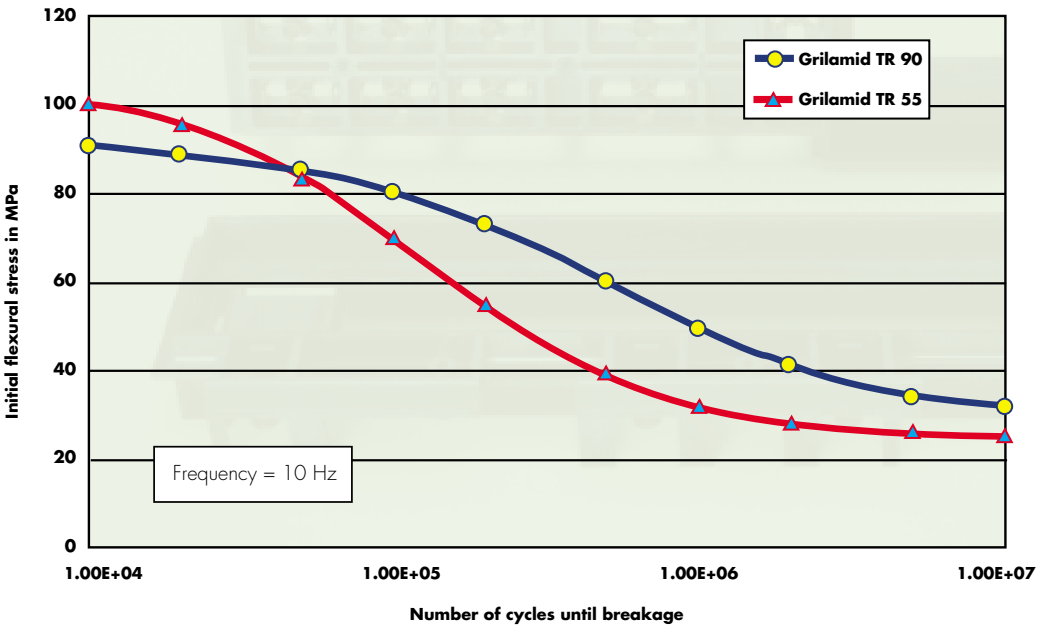
Creep curves for Grilamid TR90 at 23°C / 50 % r.h.



Dynamic strength of Grilamid TR

Dynamic, long-term stressing can lead to failure of the construction material. Depending on the degree of cyclic mechanical stress, breakage occurs after a certain number of load cycles. Grilamid TR 90 exhibits extraordinary good dynamic strength: The material has fatigue strength values (10 million flexural fatigue cycles) of more than 30 MPa. Even with fatigue strength stressing of ± 50 MPa, Grilamid TR 90 still achieves 1 million flexural cycles. This means that Grilamid TR 90 is the most suitable transparent plastic material for applications with stringent requirements regarding resistance to chemicals and dynamic strength. Grilamid TR 90 is used with great success for filter bowl applications.

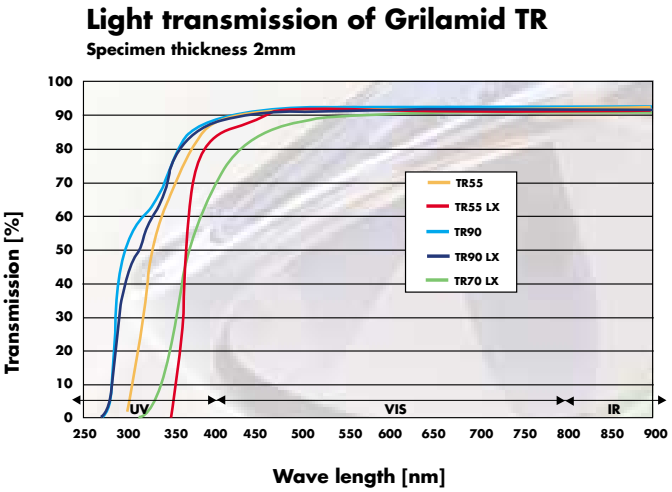
Wöhler curves for Grilamid TR
Fatigue strength in the bending range



Optical properties

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

Grilamid TR is extremely transparent, even at high wall thicknesses.

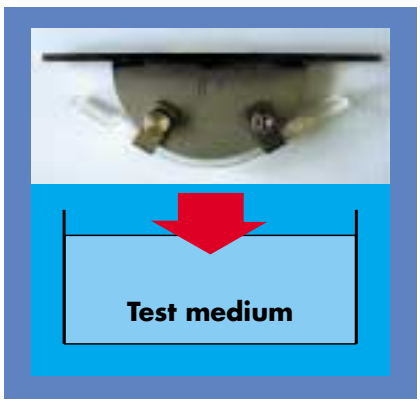


Testing method resistance to stress cracking

Testing of the resistance to stress cracking of Grilamid TR is carried out according to the bent strip test (ISO 4599). During this procedure, sample specimens are fixed to rounded templates with defined bending radii. The different radii of curvature cause the outer surfaces to be exposed to different stresses and, therefore, different amounts of flexural strain.

The test specimens are immersed for one minute in the test medium and then checked visually for signs of stress cracking.

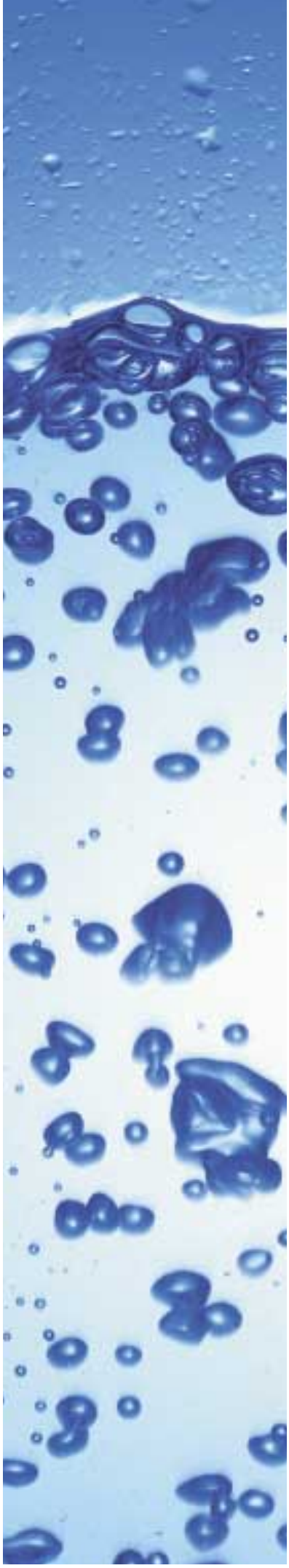
The higher the flexural strain required to cause stress cracking, the better the resistance of the plastic material to the test medium..



Resistance of Grilamid TR products to stress cracking

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

	Grilamid TR 55	Grilamid TR 70 LX	Grilamid TR 90
Acetone	20	20	>40
Butyl acetate	10	20	15
Cyclohexanone	20	5	15
"descaling agent" (Amido sulphuric acid)	>40	>40	>40
Diesel fuel	>40	>40	>40
Diethyl ether	20	20	40
Dioctylphthalate	>40	>40	>40
Ethanol	0	5	>40 T
Ethyl acetate	20	20	30
Ethyl methyl ketone	20	20	>40
Isopropanol	10	20	15 T
Isopropanol 80%	20	20	>40
Methoxypropyl acetate	20	20	15
Methyl isobutyl ketone	20	20	15
Mineral oil (ASTM no. 3)	>40	>40	>40
n-Hexane	40	>40	40
Nitro diluent	20	20	20
Peppermint oil	30	35	30
Petrol (ASTM Fuel C)	30	35	40
Petrol (FAM B)	30	35	>40 T
Petroleum ether 40-60°C	40	>40	30
"Taski Cleaning Fluid R20-Strip F41 10%"	>40	>40	>40
Toluoene	30	35	40
Xylol	30	35	>40
T = craze formation			



Resistance to chemicals

Influencing factors

Within the material group of engineering plastics, polyamides are characterised by their very good resistance to chemicals. Apart from concentrated acids, only a very few chemicals affect polyamides.

The chemical resistance of plastics is dependent on their molecular structure, the type of chemical (e.g. acid, lye, polar or non-polar solvents), temperature and contact time.

Type of chemical

Differentiation is made between physically active and chemically active chemicals. Physically active solutions cause reversible changes such as swelling or softening.
Chemically active solutions change the material in an irreversible way in that it is dissolved, destroyed through oxidation or degraded by other chemical reactions.

Temperature

The ambient temperature also has an influence on the resistance of plastic materials to chemicals. The effect of the chemicals on the plastic is stronger and more rapid at higher temperatures.

Contact time

The length of exposure is also important. The longer the contact time, 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 exhibits good, in some cases, very good resistance to chemicals.

The comparison table given on the following page shows the behaviour of different amorphous thermoplastic materials after they have been in contact with selected chemicals.

Testing

Tests to determine resistance to chemicals are carried out at room temperature and at selected application temperatures. Characteristic property values such as change in weight, length or volume, tensile strength at break and elongation at break are taken as testing criteria.

Qualitative evaluation is given using the terms «resistant», «limited resistance» or «not resistant» and refers to a non-stressed condition at the given testing temperature.

Grilamid TR products after long-term immersion in chemicals

	Temperature	Grilamid TR 55	Grilamid TR 70 LX	Grilamid TR 90
Acetic acid 10%	23°C	•••	•••	•••
Battery acid (H2SO4 36%)	23°C	••	••	••
Brake fluid (DOT 4)	23°C 100°C	••• ••	••• •• (yellowish)	••• •• (yellowish)
Caustic potash 50%	23°C	•••	•••	•••
Descaling agent	23°C 100°C/60h	••• ••	••• ••	••• ••
Diesel from filling station	23°C 60°C	••• •••	••• •••	••• •••
Ethanol 100%	23°C	o	o	o
Ethylene glycol/water 1:1 (antifreeze)	23°C 108°C	••• o	••• •• (yellowish, slightly cloudy)	••• o
Formic acid 10%	23°C	••	••	••
Grease, mineral oil based	23°C 85°C	••• •••	••• •••	••• •••
Grease, silicon oil based	23°C 85°C	••• •••	••• •••	••• •••
Grease, synthetic	23°C 85°C	••• ••	••• ••	••• ••
Hydrochloric acid 1%	23°C	•••	•••	•••
Methanol 100%	23°C	o	o	o
Mineral oil ASTM no. 3	23°C 100°C	••• •••	••• •••	••• •••
n-hexane	23°C	•••	•••	•••
Petrol from filling station (Super lead-free)	23°C 60°C	••• •••	••• •••	••• ••
Petrol, containing alcohol	23°C 60°C	o o	o o	o o

•••	Resistant. No or little change in weight or dimensions, no damage.
••	Limited resistance. Changes in weight or dimensions after longer periods - possibly reversible. Irreversible changes also possible. We recommend contacting us before use.
o	Not resistant. May be used under specific conditions (short exposure/contact time).

Specimens immersed at 23°C were tested for mechanical properties after 5000 hours. Other specimens immersed at higher temperatures were tested after 3000 hours (if no other figures are given).

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Suitability for sterilisation processes

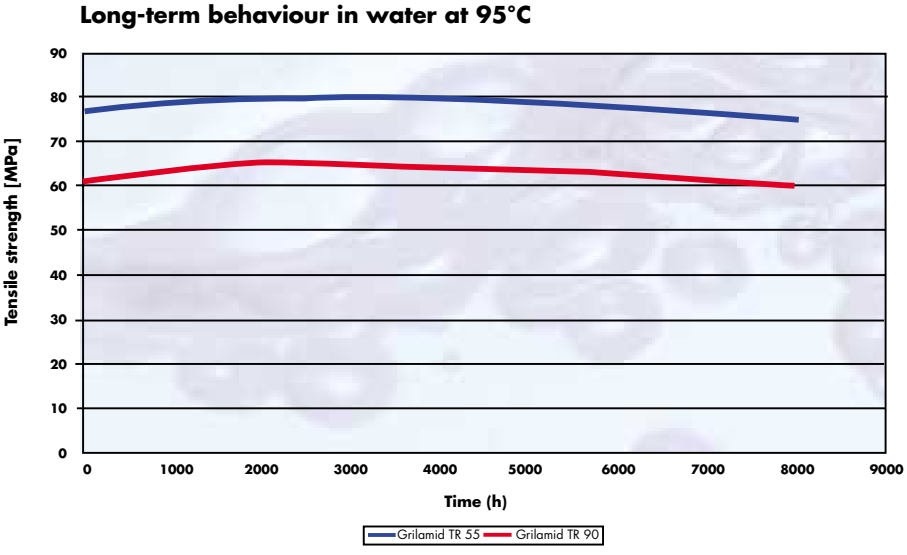
All Grilamid TR grades are generally suited for sterilisation. The table given below shows a summary of conventional sterilisation methods and their effects on Grilamid TR.

	Grilamid TR 55	Grilamid TR 70 LX	Grilamid TR 90
Steam, 121°C, 1 bar, 30 minutes/cycle	•••	•••	••
Steam, 134°C, 2 bar, 7 minutes/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. Please contact us before use.
o	Not resistant. The material quickly becomes cloudy and brittle or misshapen.

Resistance to hydrolysis - hot water

Grilamid TR 55 and Grilamid TR 90 have a good to very good resistance to hydrolysis in hot water up to 95°C. 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). Hydrolysis resistance of Grilamid TR at a temperature of 95°C is summarised in the following graph.



Resistance to weathering

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

Resistance to weathering of a material is dependent on its polymer structure and kinds of reinforcement (glass, mineral, carbon black) it contains. 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 xenone radiation according to ISO 4892). Following this method, tensile testing specimens are subjected to artificial accelerated weathering in our material testing department. The mechanical and optical properties of the specimens are measured after given periods of time.

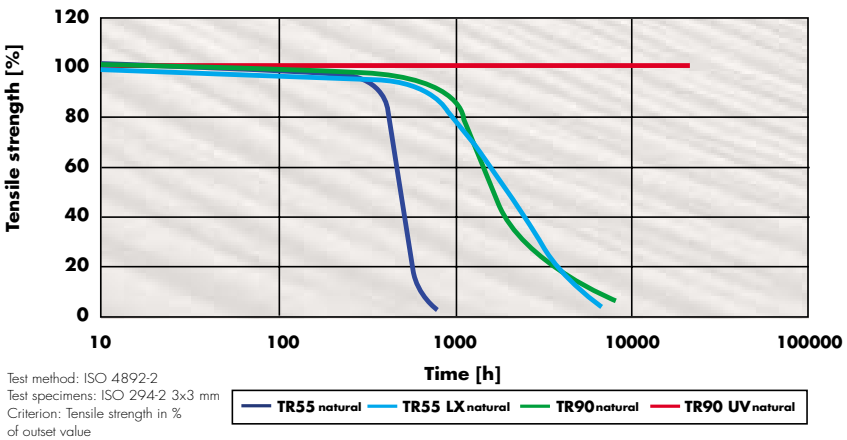
Grilamid TR exhibits generally good resistance to weathering. Grilamid TR 55 is listed as f1 according to UL 746 C and is, therefore, suitable for use in exterior applications.

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

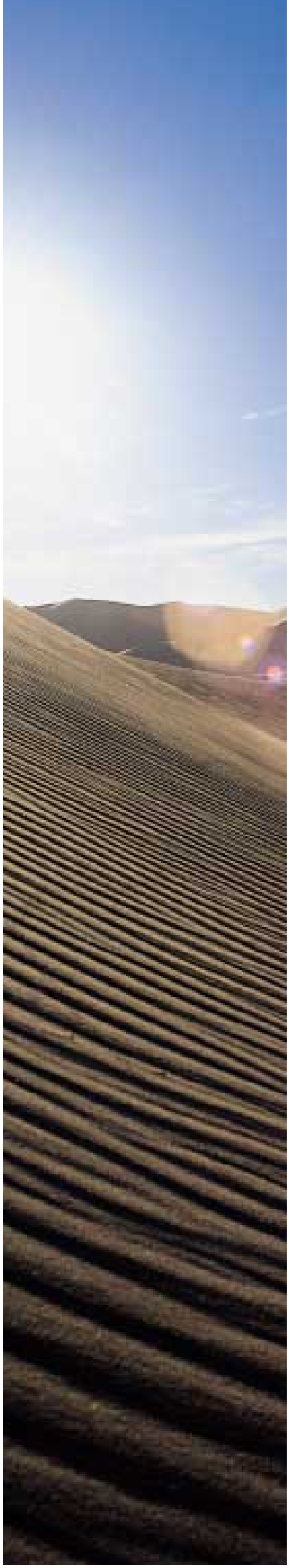
Development of Grilamid TR 90 UV was undertaken in order to produce a material to satisfy the most stringent specification requirements. The good resistance to weathering exhibited by Grilamid TR 90 in combination with an optimised UV stabiliser system results in a first-rate transconstruction material. Even after 20,000 hours of exposure to xenon light at a permanent temperature of 65°C and with regularly changing dry/water spray cycles, no noticeable change can be seen 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 exterior applications even under the most extreme climatic conditions.

Tensile strength of Grilamid TR after weathering



Test method: ISO 4892-2
Test specimens: ISO 294-2 3x3 mm
Criterion: Tensile strength in % of outset value



Approvals

Grilamid TR in contact with foodstuffs

EU

In the directives 02/72/EC and 90/128/EEC and its supplements, the European Union has stipulated the conditions to be fulfilled by polymers in contact with foodstuffs. According to these guidelines the polymer matrix of Grilamid TR grades fulfil the requirements for contact with foodstuffs. The EU directives have been incorporated into the national legislation of the EU member countries and Switzerland.

Materials may only be used in applications involving direct contact with foodstuffs when any different additives they contain such as lubrication agents etc., are also approved for this kind of application.

The following Grilamid grades satisfy the EU guidelines for repeated direct contact with foodstuffs:

- **Grilamid TR 55 natural**
- **Grilamid TR 70 LX natural**
- **Grilamid TR 90 natural**

Both global and specific migration of the monomers must be tested on the end product. Please contact the responsible salesman for more detailed information.

USA

According to FDA (21 CFR 177.1500 (11)), Grilamid TR 55 natural is approved for contact with foodstuffs having an alcohol content of maximum 8 %.

Grilamid TR in contact with drinking water

If fittings are to be used in contact with drinking water, the fitting itself and, in some cases, the material of which it is made, must be approved for use according to the regulations of the respective countries.

Germany (KTW):

The following products have been tested according to the "KTW Recommendations of the federal health agency" and are approved for use in applications involving contact with hot drinking water (90°C):

Grilamid TR 55 natural
Grilamid TR 90 natural

UK (WRAS):

The following materials have been tested and are "Water Regulations Advisory Scheme (WRAS) - approved products" (or WRC). They are thus approved for use in the UK in applications involving hot drinking-water (85°C):

Grilamid TR 55 natural
Grilamid TR 90 natural

USA (NSF):

The NSF (National Sanitation Foundation) tests materials for their suitability for use in drinking water applications. The following Grilamid TR grades are certified suitable for use in warm (60°C) or hot-water (82°C) applications as per NSF, Standard 61 ("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 70 LX natural (82°C),
Grilamid TR 90 natural (82°C),
Grilamid TR 90 grey 9272 (82°C),
Grilamid TRV-4X9 natural (82°C),
and Grilamid TRV-4X9 black 9208 (82°C).

Grilamid TR in contact with skin

Grilamid TR 55 LX natural and Grilamid TR 90 natural satisfy the requirements as per the standard ISO 10993 (EN 30993) for long periods of skin contact.

Approvals for medicinal applications according to USP Class VI

Grilamid TR 70 LX natural fulfils the requirements of USP 23 Class VI (USA).

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Drying and storage

Grilamid TR is delivered ready dried and sealed in air-tight containers. If these are stored correctly, further drying before processing using injection-moulding methods is not necessary. However, pre-drying of Grilamid TR is an absolute necessity before use in extrusion processes. Sealed, undamaged sacks can be stored, protected from the elements, for several years without any loss of quality. We recommend maximum storage periods of six months for material which are intended for use in applications involving stringent requirements for optical quality. Storage is recommended in a dry room in such a way that sacks are also protected from damage. Material from damaged or ripped sacks should be transferred to sealable, metal containers and in some cases, drying before use may be necessary.

It is important, particularly during cold seasons of the year, that material to be processed is stored in its unopened sacks for a few days in the processing plant so that the granules reach room temperature. This prevents the formation of condensation on the surface of the granules when the sacks are opened. This temperature adjustment can be achieved more quickly if the sacks are stored in a warmer location.

The packaging should be opened shortly before processing is to take place. If only a partial amount is to be used from an opened sack, it is recommended that the remaining material is resealed in an air-tight metal container with as little empty air space as possible. Metal canisters with screw lids have been found most suitable. The plant hopper should be covered to prevent air circulation. A hopper heating system or hopper dryer with temperatures of max. 80°C should be used during long dwell times with granules in the hopper.

In comparison to other polyamides, Grilamid TR absorbs only a very small amount of moisture from the air. Material which is in contact with the air for any length of time may reach a processing critical water content of more than 0.1% in the top layer of granules in less than two hours. A too high water content may become apparent through bubbles or foam in the melt cake or silvery streaking on the surface of the moulded parts.
If drying is necessary it can be carried out using a vacuum oven or dry-air drier. Circulating air ovens are not recommended as the drying capacity is greatly dependent on the humidity of the air outside the oven.

Vacuum oven:	4 - 8 hours at 80°C
Dry-air drier:	4 - 6 hours at max. 80°C. At higher temperatures there is a danger of yellowing. A dew point of -30°C as value for the moisture content of the dry air ensures a good drying result.

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Processing using injection-moulding methods

Grilamid TR can be processed using conventional injection-moulding equipment and has a wide processing window due to its amorphous structure.

Plasticising unit

We recommend use of a wear-protected, universal three-zone screw with a compression ratio of 2:1 up to 2.5:1, a length of 18 - 22 D and a non-return valve.

The screw diameter should be chosen so that the charge volume is at least 50% of the maximum feed volume of the machine. Utilisation of 60 - 80 % of the maximum feed volume is ideal and allows long melt dwell times to be avoided.

Nozzle

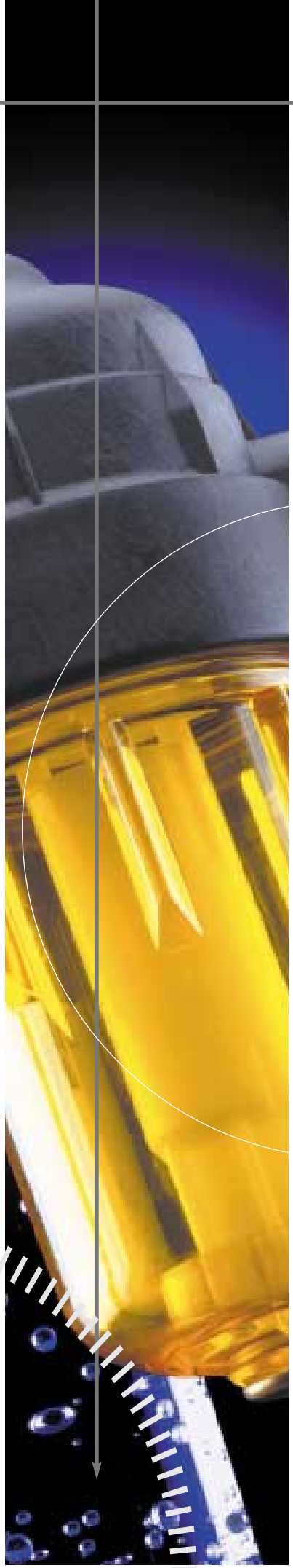
Open dies with conical taper towards the tip allow optimum flow behaviour with minimum pressure loss. The nozzle should have a separately controlled heating system.
Shut-off nozzles are suitable for preventing melt flow from the nozzle, whereby roll or sliding shut-off nozzles exhibit lower flow resistance than needle valve nozzles. Use of longitudinal, self-closing nozzles is not recommended.
After metering the nozzle should be lifted from the mould, except when hot runner feed systems are used. If the nozzle is left in contact with the mould the drop in temperature may cause solidification resulting in the formation of a so-called "melt slug". This can cause blemishes on the surface of the injection-moulded article. In addition, it is also possible that a sharp increase in pressure takes place in the nozzle, causing a change in moulding conditions.

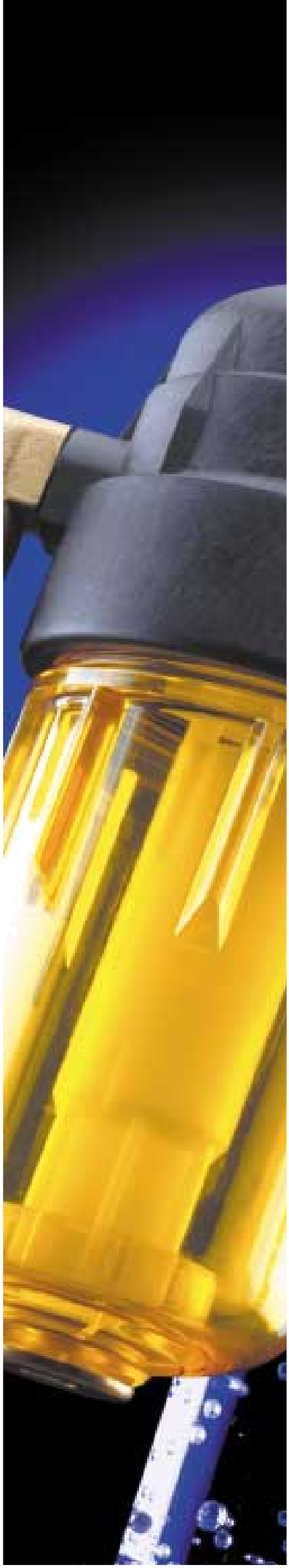
Clamping unit

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

Processing temperatures

Depending on the model of plasticising unit being used, the cylinder temperatures should lie between 240°C and 280°C (melt temperature 260°C – 290°C). A melt temperature which is too low can lead to the formation of internal stresses in the injection-moulded parts while temperatures above this given range, in particular in combination with long dwell times, can lead to thermal degradation with changes to the mechanical properties and colour of the material.
Mould temperatures, which should be between 40°C and 120°C depending on the model, are of significant importance for injection-moulded parts with a low level of internal stressing. Elevated mould temperatures generally lead to minor internal stresses. Detailed processing recommendations can be found in the corresponding material data sheets.





Shrinkage and holding pressure

Holding-pressure is a very important factor for the manufacture of dimensionally accurate technical parts. This pressure compensates column contraction caused by solidification of the melt. Compared to partially crystalline plastics, Grilamid TR exhibits very low shrinkage values which are practically identical both longitudinally and transversely in the direction of injection. This allows parts with extremely low warping or distortion to be manufactured using this material. Holding pressure should be adjusted at a level just high enough to prevent sink marks. In combination with a decreasing holding pressure profile, this allows injection stresses to be kept to a minimum.

Mould design

The usual guidelines applicable for all thermplastic materials are valid for mould design. An internal mould pressure of max. 800 bar should be taken as guide value for mechanical stressing. Hard-wearing tool steel (through or case-hardened steel) should be used for the moulding areas.

Grilamid TR gives a very accurate reproduction of the mould surface. In order to obtain moulded parts with glossy surfaces the mould surfaces must be finely polished. Rough surfaces may cause problems with mould release. Structured surfaces require a mould release draft angle corresponding to the depth of the structuring.

Gating system

As a rule, all gating systems are suitable for use when processing Grilamid TR. 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.
Pin or tunnel gates are often used for economical reasons. A draft angle of 2 - 4° is recommended when using a central sprue. The sprue diameter should be 1.4 x larger than the largest wall thickness of the part (min. 4 mm) and the gate diameter approx. 0.8 x the largest wall thickness in order to achieve optimal filling of the mould with no premature freezing. Hot runner systems are also suitable for use during processing of Grilamid TR. In general, externally heated runners and dies have proven suitable due to their flow-favourable design. Due to their complex nature, the choice and settings of the runner and die should be made together with the manufacturer of these systems.

General notes concerning the design of shaped parts

- avoid sharp edges and notches
- avoid marked variations in wall thickness
- avoid positions where the melt can collect
- eliminate weld lines as far as possible; if unavoidable, place them in low-stressed positions with high wall thicknesses
- allow mould venting at the end of flow paths or in weld line
- plan a demoulding draft angle (around 1°)

Processing by extrusion

Grilamid TR can be melted and compounded using extruders suitable for processing polyamides. Three-zone screws with a L/D ratio ≥ 24 and a compression ration of 2.5 – 3.5 : 1 have proved suitable. It is recommended to maintain the hopper zone at a constant temperature between 60°C – 90 °C.

Drying

Grilamid TR reacts very sensitively to the moisture content of the granules during extrusion. Streaking of the part surface is an indication that the water content of the granules is too high. It is absolutely necessary that Grilamid TR is pre-dried before being used in extrusion processes.

Temperature settings

Depending on the type of equipment used, the temperature settings on the extruder should lie between 220°C and 280 °C. Generally, the ideal melt temperature is between 230°C and 280 °C.

Pipe extrusion

Due to its amorphous structure, Grilamid TR solidifies very quickly and over a very narrow temperature range. Contact with cooling water must be avoided before final shaping has been achieved.

Injection stretch blow moulding

Grilamid TR 55 and Grilamid TR 90 can be easily processed using conventional single-stage injection stretch blow moulding equipment. The following machine settings have proved suitable:

Cylinder temperatures:	260 - 290°C
Heating canal temperature:	275 - 295°C
Nozzle temperature:	280 - 300°C
Temperature of the injection mould:	15 - 100°C
Temperature of the blow mould:	60 - 140°C

The recommendations given in the chapter «Processing using injection-moulding methods» (page 23) are otherwise valid. It has been found to be an advantage if Grilamid TR is not blown at maximum pressure in order to prevent formation of surface defects such as «orange skin effect». Wherever possible, higher or maximum pressures should be used only towards the end of the blowing process.

Post-treatment

Bonding

Grilamid TR can be bonded very well using suitable adhesives.

Reaction adhesives (both single and two-component systems) are particularly well suited for bonding Grilamid TR.

The most common reactive adhesives are:

Single-component systems:

- Cyanacrylate and methacrylate adhesives are well suited for bonding Grilamid TR to metal; small bond areas with fine joints, very rapid setting.

Two-component systems:

- Polyurethane adhesives
- Epoxy resin adhesives; longer pot life (hardening time); gap filling; large areas to be bonded.

A significant improvement in the bonding quality can be achieved with pre-treatment.

Kinds of pre-treatment:

- Mechanical removal: scrubbing, grinding, sand-blasting
- Electro-chemical treatment: Corona discharge, low-pressure plasma
- Thermal: flame treatment
- Chemical: treatment through use of a primer; adhesive manufacturers offer suitable primer systems

The choice of suitable adhesive must be decided upon separately for each application. This is because apart from the materials to be bonded, the joint geometry, glueline and surface quality all have a great influence on the resulting bond.

Welding

All welding methods developed for use with engineering plastics are suitable for welding Grilamid TR. Shaped parts made of Grilamid TR can be welded very efficiently using infra-red/heated tool welding, ultra-sonic, laser and vibration welding methods.

In particular, material combinations of partially crystalline, Grilamid grades reinforced with glass fibres (e.g. Grilamid LV-3H, Grilamid LV-5H) with amorphous Grilamid TR grades such as Grilamid TR 55 or Grilamid TR 90, allow non-positive bonds, e.g. for viewing glasses in housings, and open up interesting design possibilities.

When using ultra-sonic welding, the best results are obtained in the weld zone. This means that this process is best suited for small parts. Ultra-sonic welding can also be used to embed metal threads, for riveting and for beading.

A combination of two materials, one allowing penetration of the laser beam, the other absorbing the laser beam, are necessary to carry out laser-beam welding. Special, laser-beam absorbing grades of Grilamid TR are available on request.

The highly transparent Grilamid TR grades which allow penetration by the laser beam, can be welded using laser-welding methods when a light-absorbing film with a thickness of maximum 75 µm is placed between the parts to be joined.

Sandwich moulding

Similar to classical welding methods, Grilamid TR can be bonded very successfully with partially crystalline Grilamid materials using injection welding processes (multi-component injection moulding).

The combination of Grilamid TR and flexible Grilamid ELY grades allows very strong hard/soft bonds to be created.

Thermoplastic polyurethane elastomers (TPE-U) or bond-modified styrene elastomers (TPE-S) are also suitable for use together with Grilamid TR in hard/soft combinations .

Screw fastening

Injection-moulded parts made of Grilamid TR can be fastened very successfully using screws which form their own threads (self-tapping and thread-cutting screws).

Please contact our Technical Advisory Service for further information about post-treatment of Grilamid.

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Painting

Grilamid TR does not contain plasticisers which could have a negative effect on paint adhesion.

The suitability of paint systems used for colouring plastic materials is dependent on the solvents used and the required drying temperature.

Two-component polyurethane paints have proved particularly well suited for painting Grilamid TR. Use of special formulations of the paint components allows, for example, elasticity values to be adjusted and excellent weathering and light stability to be achieved. In order to accelerate curing, painted parts can be cured in ovens for around 60 minutes. The paint system selected should cure at a temperature of maximum 50°C.

Before being painted the parts should be cleaned of any dust or residue mould release agent. Pre-treatment to increase the surface tension is not usually necessary.

Recommendations and know-how from paint manufacturers should be taken into consideration during the selection of paints and solvents to be used. It is recommended that preliminary tests are always carried out.

Printing

Special pre-treatment of Grilamid TR before using conventional printing methods is not necessary. In practice however, pre and post-flaming have been found to give a durable printing result.

Laser technology is being increasingly used for marking and lettering as it results in scratch-resistant, durable marking and is a very flexible application process. Similar to laser-beam welding, laser-absorbing pigments in the plastic are necessary in order to carry out laser marking. Corresponding laser-printable grades of Grilamid TR are available on request.

Heat embossing

Heat embossing with suitable embossing film can be carried out on Grilamid TR without problem.

Metal plating

Injection-moulded parts made of Grilamid TR can be metal-plated using conventional high-vacuum methods.

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Technical advice and customer services

We offer advisory services and know-how to our customers starting with development work and continuing right through to serial manufacture of a part. Our customer services provide quality, reliability and technical support.

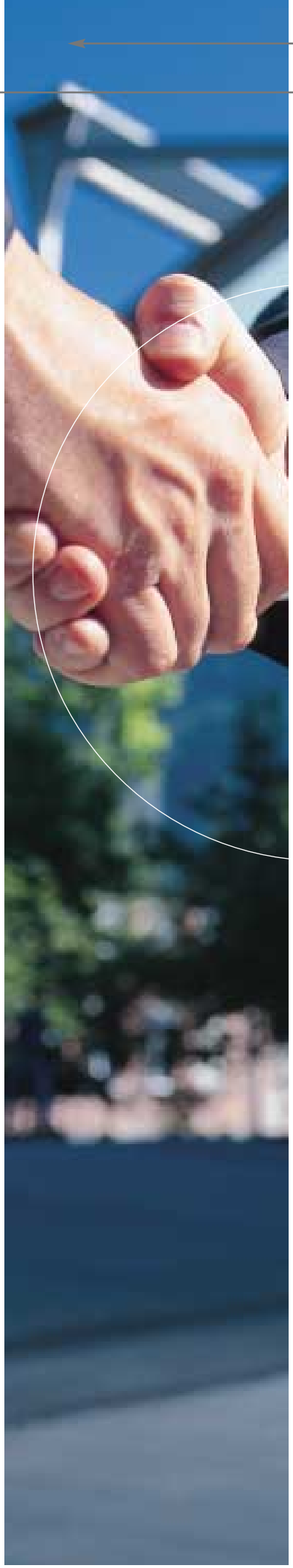
- We draw up a range of materials optimally suited for your application.
- Our advisory services department is equipped with modern injection-moulding units and extruders.
- Our materials are continually subjected to quality control and assurance procedures in order to offer you high-performance products.
- Modern, in-company test laboratories are available for mechanical, thermal, electrical and chemical property tests.

CAE - Simulation of mould construction, manufacturing and stressing

Using computer-assisted engineering systems, EMS-GRIVORY application development centres are able to offer customers a wide range of supporting measures in this sector. CAE systems used include the MOLDFLOW programme modules MF/Flow, MF/Cool, MF/Fiber and MF/Warp for simulation of injection moulding processes and the finite element FE programmes I-DEAS and ANSYS for mechanical mould design and layout. Rheological simulation enables the optimal positioning of the gate to be determined before manufacturing of the mould is begun. These programmes are also useful when changes to existing moulds are necessary as they help to determine the most goal-oriented 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 warping of shaped parts. Part design using FE analysis provides information about highly stressed areas. This allows weak points in the design to be determined and corresponding modifications to be made. Using the 3D CAD systems I-DEAS and CATIA in combination with VDA, IGES and STEP interfaces, EMS-GRIVORY is capable of using the customer's own 3D-CAD data for simulation calculations.

Prototype moulds minimise risks

The key to success is rapid realisation and quick implementation of a good idea. EMS-GRIVORY can help limit risks during prototype mould construction and reduce time expenditure and costs. Here again, MOLDFLOW and FEM simulations can be carried out and a pilot series of parts manufactured with a minimum of cost expenditure. These parts can then be used in practical tests before serial production begins. This method of preparation for serial manufacture reduces expenditure and eliminates the need to carry out expensive modifications to manufacturing moulds after the start of serial production.



Test facilities

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

Our instrument infrastructure enables us not only to determine the standard mechanical, thermal and electrical property values of our materials for use in data sheets and approvals, but also to provide practical support for research and development work and application development.

- Our mechanical testing laboratory is equipped with modern tensile testing machines, automated impact testing apparatus and devices to determine the creep behaviour of plastic materials in air and liquid media.

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

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

- Chemical and process-technical tests ensure that the high quality levels of our products can be properly monitored and consistently high prproperty values guaranteed.

We can also provide support for specific problems which our customers face. In order to test the dynamic long and short term stress behaviour of Grilamid TR we have developed a pneumatic flexural fatigue testing device.

In addition, our material testing department can make use of a variety of additional equipment such as the EMS-P Tester (determination of the permeability of fuel 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 testing shaped parts made using extrusion blow-moulding processes) and many more.

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

CAMPUS

Since 1989 EMS-GRIVORY has taken an active part in the creation of the CAMPUS data bank. Currently, our testing laboratories have characterised some 150 construction materials according to the CAMPUS profile regarding physical and process-technical properties. These are shown in both tabular (primary property values) and graphical (functional) form. Material descriptions, typical applications and processing information supplement the product profile.

CAMPUS stands for Computer Aided Material Preselection by Uniformed Standards.

The data bank contains a careful selection of meaningful test results which accurately describe the property profile of a material. The test bars used to obtain these test results are produced under standardised injection-moulding conditions and testing itself is carried out according to uniform ISO standards.

The particular advantage of this data bank is that customers can make a direct comparison of the properties of different products from more than 40 material manufacturers. Distribution of CAMPUS has allowed the uneconomical duplication of specifications and test methods to be limited, while at the same time opening up new possibilities for the rationalisation and automation of testing processes for moulding compounds.

CAMPUS CD's can be obtained by customers on request. The data bank programme and the CAMPUS data can also be downloaded easily and at no cost from our homepage - www.emsgrivory.com.

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Quality standards

Our quality management system is based on the international standards ISO 9001:2000 and is certified by the Swiss association for quality and management systems, "Schweizerischen Vereinigung für Qualitäts- und Management-Systeme" (SQS). We are currently introducing the regulations from the new standard ISO/TS 16949 developed by the automotive industry.

At EMS-GRIVORY our management system is process-oriented; our highest goal is customer satisfaction and our efforts are concentrated on conformance with quality requirements and 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 interdepartmental teams working within the score of simultaneous engineering. The team members do not think and act solely in categories of their departments, but are striving to attain a common goal. Modern technology (such as statistical test design) and preventive methods (such as failure mode and effect analysis) play a central role. The guiding principle of the project management is "avoiding mistakes instead of correcting mistakes".

We apply the product release requested by our automotive customers to new or modified products.

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

Continual improvement of products, services and productivity is the subject of an official improvement programme to which all employees are 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.

Grilamid TR Link

Further information can be found on our homepage:

www.emsgrivory.com

All product and market-segment specific brochures can be downloaded directly from our homepage. Look under "Products" or "Markets" to find the required product/application page.
All technical data sheets are available as pdf files.

Orders for the following brochures can be made to our public relations department quoting the corresponding code number:

Product data

- Comparison table Grilamid, Grivory, Grilon: Comparison of mechanical, electrical, thermal and general properties
  Code: 2.002
- Product review: Engineering plastics
  Code: 2.001

Technical data

- Notes concerning injection moulding of Grilamid, Grivory and Grilon
  Code: 7.001
- Injection moulding equipment
  Code: 7.005
- Designation of EMS-GRIVORY thermoplastic materials according to ISO and DIN standards
  Code: 2.003
- CAMPUS CD-Rom
  Code: 11.002

Market segments

Automotive
- Innovative system solutions for automotive construction
  Code: 10.001

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Delivery form

Grilamid TR is delivered as cylindrical granules packaged in moisture-proof sacks of 20 or 25 kg each.

Predrying of material from unopened and undamaged sacks is not necessary. Many Grilamid TR grades are available directly from stock in the colours natural and black.

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 pre-pays disposal fees e.g. in co-operation with the RIGK organisation in Germany where customers can deposit their empty packaging containers for disposal.

Liability

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.
Note: EMS-GRIVORY cannot evaluate future health risks which may arise through direct contact of its products with blood or tissue. For this reason, EMS-GRIVORY cannot promote or use its materials in medical applications where direct contact with blood or tissue occurs.

Domat/Ems, December 2003

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