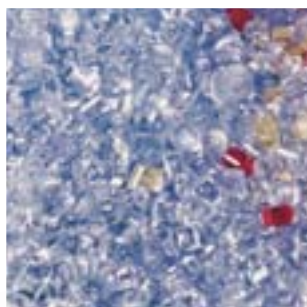
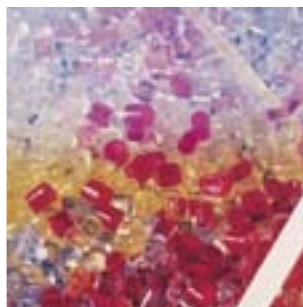
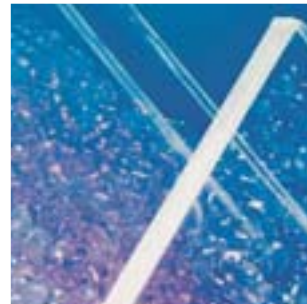
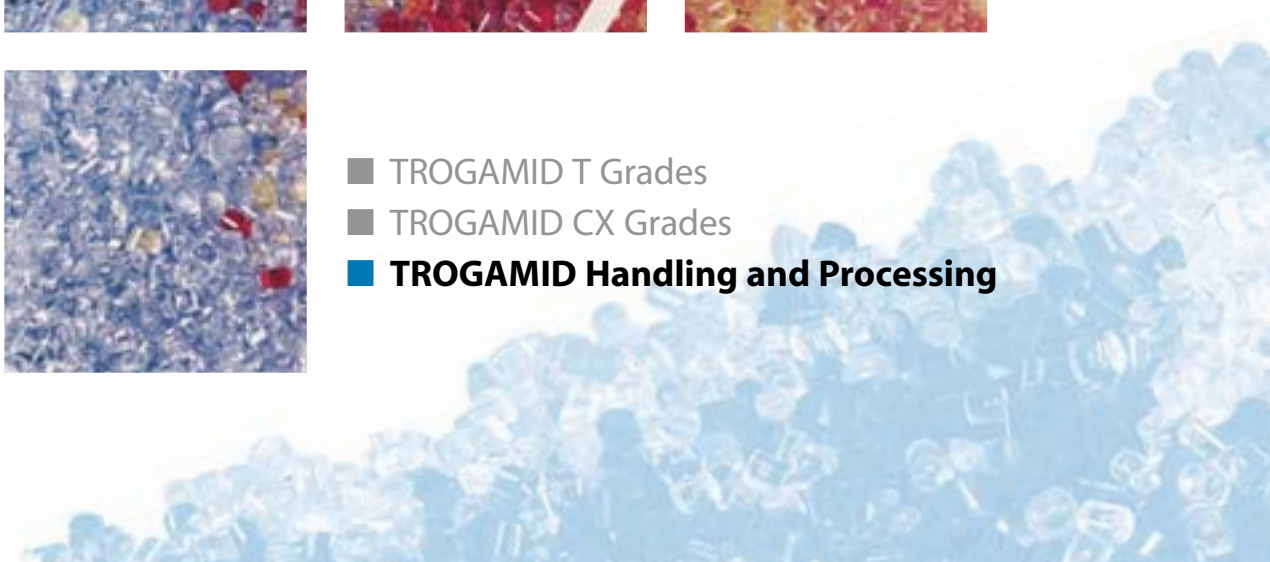




Transparent polyamides with an outstanding combination of properties



- TROGAMID T Grades
- TROGAMID CX Grades
- **TROGAMID Handling and Processing**





### Handling and Processing of TROGAMID

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# 1 Introduction

## 1.1 Nomenclature

The TROGAMID product range of Degussa AG's High Performance Polymers Business Unit consists of basic products and compounds that are distinguished by their permanent transparency and high chemical resistance. T grades comprise products based on polyamide 6-3-T (PA 6-3-T) only, while BX grades cover PA 6-3-T blends containing other semi-crystalline or amorphous polyamides. New, specially designed polyamides are designated as CX grades and are followed by a four-digit number.

This four-digit number has now specific meaning, e.g., viscosity number or composition. Table 1 provides further information about the nomenclature of the TROGAMID range according to the commonly used DIN/ISO standards.

**T grades:** PA 6-3-T-based polymers and compounds made of trimethyl hexamethylene diamine and terephthalic acid, e.g., TROGAMID T5000 or TROGAMID T-GF35.

**BX grades:** PA 6-3-T and semi-crystalline polyamide blends, reinforced and unreinforced, e.g., TROGAMID BX7304 or TROGAMID BX9724.

**CX grades:** Special polyamide grades made of other monomers, e.g., TROGAMID CX7323 or TROGAMID CX9701.

**Table 1:** Nomenclature of semi-aromatic/aliphatic amorphous polyamides according DIN 16773 and ISO 1874

TROGAMID	DIN 16773 nomenclature *)	ISO 1874 nomenclature	Monomers
<b>T grades</b>	PA 6-3-T	PA NDT/INDT	trimethyl hexamethylene diamine terephthalic acid
<b>BX grades</b>	PA 6-3-T/XX	not applicable	trimethyl hexamethylene diamine terephthalic acid
<b>CX grades</b>	not applicable	PA PACM 12	cycloaliphatic diamine dodecanedioic acid

\*) DIN 16773 affords a further differentiation, e.g., the viscosity number; further information can be provided upon request.



This brochure covers the processing and the pre- and posttreatment of our TROGAMID compounds. More information and details can be obtained from the Technical Marketing Department of the Business Unit High Performance Polymers.

## 2 General Information

### Supply and coloring of TROGAMID compounds

All products made by the Business Unit High Performance Polymers are subject to strict quality control and quality assurance in accordance with ISO 9001 and QS 9000. TROGAMID is commonly supplied as natural-colored granules in moisture-proof bags. In the case of large orders, we can supply TROGAMID in special colors and in big bags upon request. If the packaging is unopened, TROGAMID can be stored for at least two years at room temperature.

### Drying

TROGAMID, pre-dried to a moisture content of not more than 0.1 wt.-% water, is supplied in moisture-proof bags. Thus, if the original bag has not been damaged, you do not need to pre-dry the granules any further. In cold areas, please allow the bags to reach ambient temperature before opening them so that any moisture in the air will not condense on the granules.

Under certain conditions, e.g., after a prolonged period in the machine's hopper or in the case of processing from an open bag, it will be necessary to pre-dry the granules in a dry-air drying oven (80–90 °C) for a period from 8 to 12 hours. Fresh air drying ovens will not suffice for this purpose.

In some cases, e.g., when extruding thick-walled profiles or injection-molding thick-walled parts, you should pre-dry the granules at any rate to prevent waviness.

The melt should be crystal-clear, free of bubbles and waves and produce a streak-free strand in order to obtain molded parts with superior appearance and mechanical properties.

If drying is necessary a dehumidified air drying oven should be used with a temperature setting between 80–90 °C for 8–12 hours. When using circulated air or fresh air drying ovens the process is dependent on the moisture content of the air and therefore may sometimes lead to an increase in moisture content of the granules. Therefore, this type of drying equipment is not recommended.

### Incompatibility with other thermoplastics

TROGAMID is not compatible with most other plastics, not even with other polyamides. Even if small quantities of other plastics are allowed to contaminate TROGAMID resins, the melt and the finished parts will be clouded. Additionally, the mechanical properties can be influenced. Thus, before working with TROGAMID, the plastication units of the processing machine and all other melt channels should be cleaned very carefully with common cleaning materials or with prepared TROGAMID sprue or start-up waste.



# Information

## Coloring of TROGAMID resins

TROGAMID is best colored with color concentrates based on identical TROGAMID resins. Dry coloring by tumbling with finely powdered pigments is another possibility, but it is inconvenient, since pneumatic conveying is impossible. The use of color pastes or color concentrates having a "neutral" (e.g., PE) base can lead to incompatibility with TROGAMID and hence to poor part properties (poor weld line strength or low transparency due to clouding). Therefore, it is absolutely necessary to test compatibility in each case.

## Ecology and safety

TROGAMID compounds are non-hazardous substances and are not subject to any particu-

Degradation of the material during processing is recognizable as a discoloration of the melt or in the appearance of black specks. Degraded material should be quickly removed from the machine and cooled under water to minimize any troublesome smells or fumes. At melt temperatures around 360 °C–370 °C (680 °F–700 °F), flammable gases are released. Combustion in excess air produces carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), water (H<sub>2</sub>O), and nitrogen-containing compounds as end products. Since the spectrum of crack and combustion products greatly depends on the combustion conditions, it is not possible to make any general statements here.



lar safety regulations. TROGAMID compounds are classified in the Water Hazard Class as "not water hazardous." They can be disposed of in landfills or incinerated as normal household rubbish, local ordinances permitting. Further information can be obtained from the Material Safety Data Sheet for TROGAMID, which will be shipped upon request. Reprocessing is, however, preferable to disposal and is also advisable for ecological and economic reasons.

No dangerous by-products are formed if TROGAMID is processed as directed. However, care should be taken to ventilate the working area properly. TROGAMID compounds do not contain halogenated flame retardants, e.g., polybrominated diphenyls or diphenyl ethers. No toxic pigments or additives containing cadmium are used either.

### Use of regrind

Due to its hygroscopic properties, immediate reprocessing of TROGAMID scrap is recommended. The regrind material must be free from foreign matter and dirt particles; the moisture content should be below 0.1 wt.-%. Small quantities of other polymers, even other polyamides with the exception of the same TROGAMID grade, will cause clouding of the corresponding molded parts.

If an immediate reprocessing of the scrap is not possible, sprues or defective parts should be ground and stored in moisture-proof bags immediately. A careful drying before reuse is necessary.

The quantity of regrind added to virgin material is generally dependent on the required part properties and must therefore be determined by tests on the ready molded part. If the use of regrind is allowed by the requirements and specifications of the end user, additions of up to 25 wt.-% regrind are possible.

### Viscosity number, thermal stability, flowability

TROGAMID has a wide processing window due to its amorphous structure and high level of thermal stability. Generally, any changes in flow resistance in the mold can therefore be adjusted by appropriate temperature settings (see Table 3). Nevertheless, compounds with internal flow promoters are also available.

For quality control, and to verify your processing conditions, we recommend that the viscosity number (acc. to ISO 307) of any molded part be determined. The viscosity number is related to the molecular weight of a polymer and allows one therefore to draw conclusions of the thermal stress of a molded part from processing.

Because of the high level of melt viscosity, TROGAMID shear stress should be kept as low as possible. High screw speeds or mixing and shear elements with a wrong layout affect the viscosity number of molded parts adversely. Furthermore, moisture (>0.1 wt.-%) or processing temperatures exceeding 310 °C are disadvantageous for the viscosity number, too.

### Internal stress, chemical resistance

The inherent good chemical resistance of molded parts made of TROGAMID can be reduced through the so-called internal stress.

The repeatedly observed internal stress of a part is process-related and can be more or less extremely pronounced. This internal stress is caused by cooling and shrinkage of the polymer melt in the tempered mold or the "displacement of cold fronts." Because of its low tendency to creep—a property highly regarded for engineering plastics—TROGAMID belongs to the group of polymers with a low ability to relax, which is why the internal stress level caused by processing or part geometry is maintained.



Thus "frozen" into the material, this stress, in combination with function-related stress (pressure, impact), create weak points and crack when coming into contact with aggressive materials (stress cracking). It should be mentioned that although the chemical resistance of our TROGAMID T grade is already remarkably high, we have improved it even further through the development of TROGAMID CX.

Stress due to processing are influenced by the following factors:

**Mold temperature**

Recommended mold temperature is in the range of 60 °C–80 °C. The mold temperature should be adjusted to the latter operating temperature. If the operating temperature is higher than the mold temperature, the internal stress will be released by warpage of the molded part later on. Temperature differences at the surface of the molded parts should be avoided.

**Melt temperature**

The optimal melt temperature for TROGAMID is between 280 °C and 310 °C. Short injection molding cycles and a short dwell time allow even higher temperatures, but then the thermal stability of any additives (e. g., colorants) have to be considered as well as the inherent color of the molded part.



View ports of TROGAMID CX

**Holding pressure**

After the mold cavity is filled, the holding pressure compensates for the volume contraction of the polymer melt. The time in which additional polymer melt can flow into the cavity is directly proportional to the level of holding pressure, the sealing of the gate and the wall thickness. Molding temperature and melt temperature have a negligible influence. After the part geometry and the gate is optimized the holding pressure should be chosen just high enough to avoid sink marks.

**Part geometry and gate**

Major changes in wall thickness, rips on one side only, and/or sharp edges should be avoided in the course of a part's design. Generally, symmetrically designed molding articles show less warpage than asymmetric parts. A direct feed is preferred to pinpoint gating.

**Stress relaxation/Annealing**

When molded parts are annealed, the internal stress level can be reduced significantly, and therefore the chemical resistance increases. The influence of annealing is naturally strongly dependent on time, temperature and part geometry. Usually the internal stress level of a molded part decreases during storage. This effect depends of course, also on time and temperature. Stress peaks at sharp edges or in transition zones are not compensated completely; only their level is lowered. When parts are improperly designed, additional after-shrinkage stress can arise in notched regions (for example, screw threads under tensile stress load).

# 3 Injection Molding

## General information

- In general, TROGAMID can be processed by most commercially available injection molding machines. Nevertheless, we recommend that you follow the instructions listed below when using TROGAMID in injection molding.
- In pursuing our goal of cooperating with our customers in order to find technologically intensive system solutions, we offer comprehensive application technology advice. For example, various Computer Aided Engineering (CAE) programs are employed to solve many problems of mold and part design. Among these are structural design/analysis programs, flow analysis programs for designing the mold or the cooling system, programs to predict shrinkage and warpage. Please contact our Technical Marketing Department for further information.

## Plasticating unit

Screw and barrel	<ul style="list-style-type: none"> <li>■ Three-zone screw with a length between 18 and 22 D</li> <li>■ Flight depth ratio <math>\geq 2</math></li> <li>■ Minimum flight depth: in the metering zone 2 mm, in the feeding zone 4 mm</li> <li>■ Screw and barrel diameter should be of a magnitude that allows a metering stroke between 1 D and 3 D.</li> <li>■ For more information see Figure 1</li> </ul>
Nozzle	<ul style="list-style-type: none"> <li>■ In general free-flow nozzles should be used. If shut-off nozzles are applied, keep friction as low as possible.</li> <li>■ Bore of nozzle larger than 4 mm</li> </ul>
Back flow valve	<ul style="list-style-type: none"> <li>■ Clearance between back flow valve and cylinder <math>\leq 0.02</math> mm</li> </ul>
Cleaning	<ul style="list-style-type: none"> <li>■ Light contamination (e.g., cleaning due to change of resin)               <ol style="list-style-type: none"> <li>(1) Provide a high viscosity PP.</li> <li>(2) Increase temperature settings of heating zones by 30 to 40 °C, but not above 310 °C.</li> <li>(3) Plasticate mixture with a long metering stroke and high dynamic pressure and discharge at high speed ("air shot").</li> <li>(4) Flush the plasticating unit with the new resin until no contaminants are in the melt.</li> </ol> </li> <li>■ Persistent contamination               <ul style="list-style-type: none"> <li>– In most cases persistent contamination can be removed only by mechanical cleaning of the screw, cylinder, back-flow valve, etc.</li> <li>– Sometimes a cleaning of the cylinder can be avoided by using special purging material such as RAPID PURGE, SUPERNOVA or ASACLEAN.</li> </ul> </li> </ul>

## Clamping unit

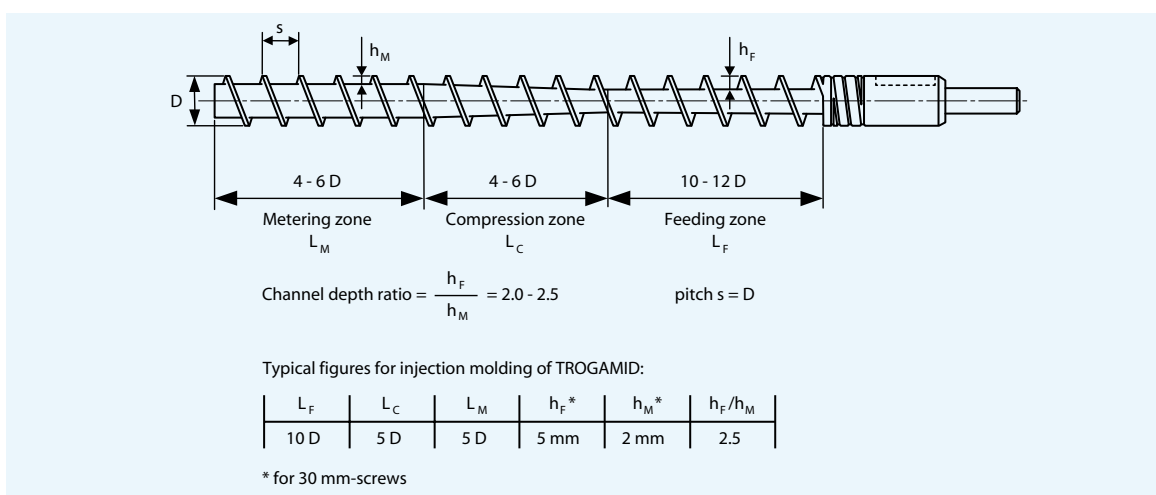
Clamping force	<ul style="list-style-type: none"> <li>■ Guideline number for maximum cavity pressure with TROGAMID resins: 300 to 500 bar</li> </ul>
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## Mold

Gate	<ul style="list-style-type: none"> <li>■ All common types of sprues, runners and gates possible</li> <li>■ Diameter or thickness of pin, submarine and film gates, depending on viscosity of resin, between 1 and 2 mm</li> </ul>
Hot runner	<ul style="list-style-type: none"> <li>■ Externally heated hot runners with open sprue nozzle recommended, nozzle diameter <math>\geq 1</math> mm</li> </ul>
Venting	<ul style="list-style-type: none"> <li>■ Venting slots in mold parting surface: 0.03 to 0.05 mm deep, 4 to 5 mm wide</li> </ul>
Cooling	<ul style="list-style-type: none"> <li>■ When processing TROGAMID CX resins, consider intensive cooling of the mold to avoid clouding of the part (Note: Parts with a wall thickness of more than 8 mm will most likely show clouding.).</li> </ul>
Shrinkage	<ul style="list-style-type: none"> <li>■ See Table 2</li> </ul>
Tool steel	<ul style="list-style-type: none"> <li>■ Suitable steels: 1.2767 (X45NiCrMo4), 1.2379 (X155CrVMo121), 1.2312 (40CrMnMo58) and 1.2343</li> </ul>

# Injection Molding

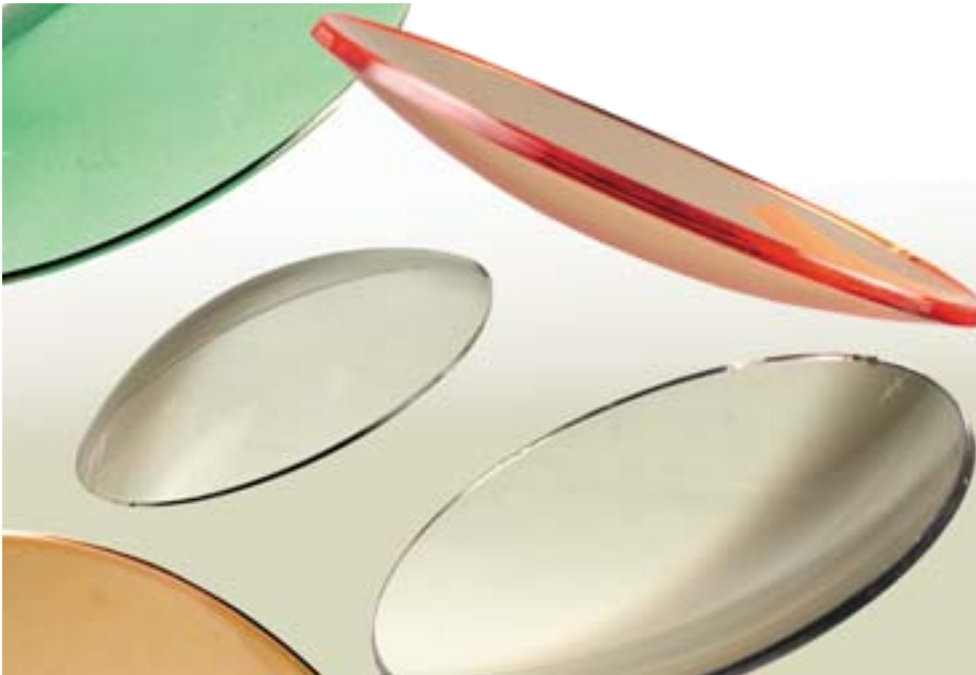
Mold (continued)	
Pressure sensor	<ul style="list-style-type: none"> <li>Use a pressure sensor within the cavity to set carefully the change-over point</li> </ul>
Mold release	<ul style="list-style-type: none"> <li>A mold release agent is normally not necessary. Some resins are available containing a demolding agent. More information can be obtained from the TROGAMID product brochures or from our Technical Marketing Department.</li> <li>Decrease of mold temperature very often facilitates part removal.</li> <li>Suitable coatings of mold surface: Ni-P-PTFE, TiAlOx</li> </ul>
Processing conditions	
Temperatures	<ul style="list-style-type: none"> <li>General settings for melt and mold temperatures see Table 3</li> <li>Decreasing temperature profile in heating zones towards hopper in steps of 10°C recommended</li> <li>If the melt temperature exceeds 310 °C, the ready molded part should be checked, e.g., by determining its viscosity number. Controlling of the melt color is not sufficient to determine possible degradation.</li> <li>Cooling of feeding zone between 40–80 °C</li> </ul>
Peripheral screw speed	<ul style="list-style-type: none"> <li>In the range of 3–12 m/min optimum, 10 m/min preferred</li> <li>Higher speeds (i.d. &gt; 18 m/min) can be applied, but might lead to problems in processing.</li> </ul>
Decompression	<ul style="list-style-type: none"> <li>After the metering is completed, a decompression could negatively affect the surface of the parts and hence should be not applied.</li> </ul>
Pressures	<ul style="list-style-type: none"> <li>Dynamic pressure: 40–100 bar</li> <li>Injection pressure: 800–1600 bar</li> <li>Pressure in holding phase: up to 1400 bar</li> </ul>
Production shutdown	<ul style="list-style-type: none"> <li>For short production breaks (e.g., up to 1 hour): empty the barrel, move screw to ultimate front position and decrease the temperature setting of the heating zones down to 150 °C.</li> <li>For long production breaks: purge the barrel with high viscosity PP or polymethyl methacrylate (PMMA), then empty the barrel, move screw in ultimate front position, switch off cylinder heatings. Remove resin left in hopper and store in moisture-proof packaging.</li> </ul>
Trouble shooting	<ul style="list-style-type: none"> <li>For trouble shooting problems with injection molding, guidelines published in common literature can be applied (e.g., "Guide to Surface Defects on Thermoplastic Injection Molded Parts", published by Kunststoff-Institut für die mittelständische Wirtschaft, Karolinenstr. 8, 58507 Lüdenscheid, Germany).</li> <li>For further information please contact our Technical Marketing Department.</li> </ul>



**Figure 1:** Design of a three-zone screw for processing of TROGAMID by injection molding

**Table 2:** Shrinkage

TROGAMID	Shrinkage acc. to ISO 294-4	
	Parallel to flow direction [%]	Normal to flow direction [%]
T5000	0.45	0.60
T-GF35	0.05	0.40
BX9723	0.10	0.70
BX9724	0.10	0.70
BX9725	0.05	0.70
CX7323	0.65	0.80

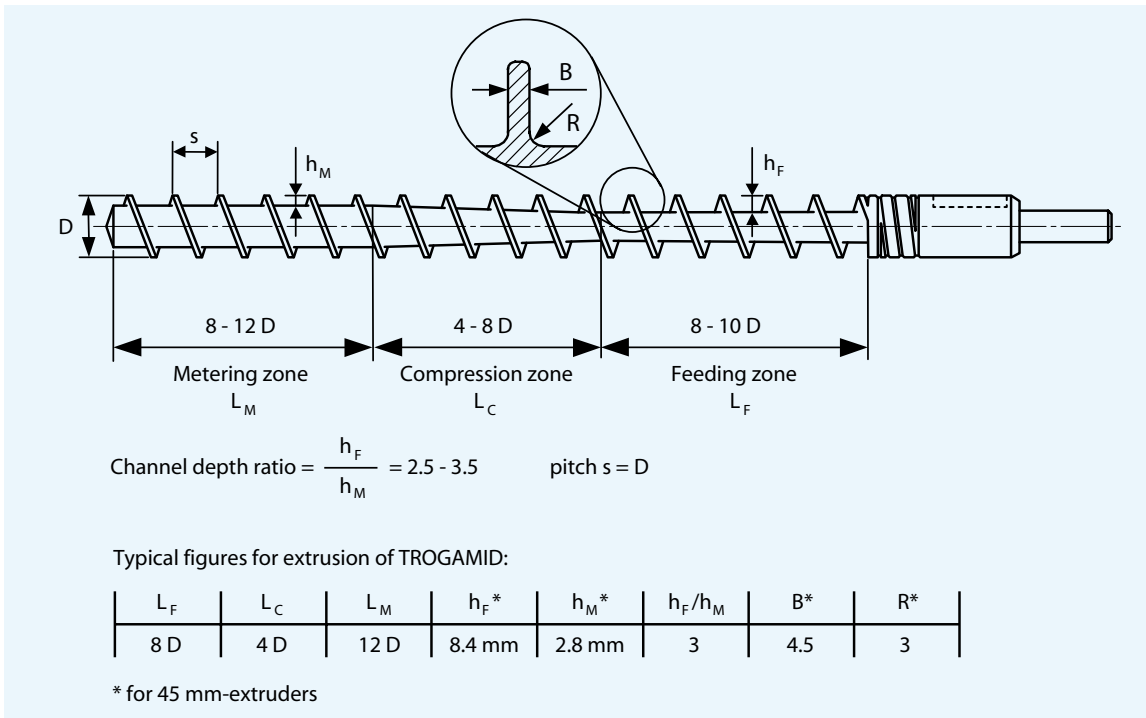


**Table 3:** General melt and mold temperature settings for processing of TROGAMID by injection molding

TROGAMID	Lower temperature limit [°C]	Upper temperature limit [°C]	Melt temperature [°C]	Mold temperature [°C]
<b>T grades</b>	250	310	260–300	60–80
<b>BX grades</b>	260	310	270–300	60–80
<b>CX grades</b>	255	310	280–300	60–80

## 4 Extrusion

General Information	
Screw and extruder	<ul style="list-style-type: none"> <li>■ Conventional three-zone screw with a length <math>\geq 24 D</math></li> <li>■ Flight depth ratio ranging from 2.5 to 3.5 : 1</li> <li>■ Suitable ratios between feeding/compression/metering zone: 2:1:3, 2:2:2, 1:1:1</li> <li>■ Radial clearance between screw and barrel: 0.1–0.2 mm</li> <li>■ Mixing and shear elements may be useful to increase melt homogeneity (e.g., processing resins colored with pigment concentrates into films)</li> <li>■ For more information see Figure 2</li> </ul> <p><u>Note:</u> Other screw designs (e.g., barrier screws) may lead to proper processing conditions as well.</p>
Breaker plate	<ul style="list-style-type: none"> <li>■ Not required for processing virgin material, recommended only as support for screen packs, e.g., when processing regrind.</li> </ul>
Temperature setting	<ul style="list-style-type: none"> <li>■ Cooling of feeding section necessary</li> <li>■ Melt temperature in the range of 265–295 °C, with decreasing temperature profile from hopper to die. The general temperature setting is very much dependent on the resin and the type of extrudate (film, profile, tube, ...) to be processed. Thus, a general recommendation cannot be given.</li> <li>■ Optimizing the temperature setting by monitoring the temperatures of the heating zones, the melt temperature and the consistency of the melt leaving the die: <ul style="list-style-type: none"> <li>– high pressure build-up and a dull surface of the melt leaving the die: increase temperature profile</li> <li>– melt with a low stability: decrease temperature profile</li> </ul> </li> </ul> <p><u>Note:</u> If there are large discrepancies between temperature setting and measured temperature, the screw design might not be suitable for processing TROGAMID</p>
Cleaning	<ol style="list-style-type: none"> <li>(1) Raise temperature of all heater bands by about 20 °C and purge by using PP (MFI 230 °C/5 kg 12 g/10 min).</li> <li>(2) Disassemble die, remove plastic residues from die and polish die.</li> <li>(3) Continue to purge extruder with PP, and lower temperature to about 170 °C.</li> <li>(4) At this temperature, replace PP with a purging mixture consisting of heat-stabilized PVC/cleaning fluid/glass fibers (ratio 98:1:1). If the PVC grade is not sufficiently heat-stabilized, degradation may easily occur.</li> <li>(5) Pull out screw and remove plastic residues from screw and barrel.</li> </ol>
Trouble shooting	<ul style="list-style-type: none"> <li>■ Pulsation of melt caused by the extruder <ul style="list-style-type: none"> <li>– Insufficient cooling of feeding section</li> <li>– Insufficient lubrication of pellets</li> <li>– Shape of pellets inhomogeneous (e.g., when processing regrind)</li> <li>– Pressure build-up of die too low</li> <li>– Improper design of feeding section (grooved/smooth)</li> <li>– Improper screw design</li> <li>– Variation of die temperature due to improper setting of control parameters for die heater band</li> <li>– Problems with motor/gear box</li> </ul> </li> </ul> <p><u>Note:</u> Pulsation of the melt can be caused by the downstream equipment as well</p> <ul style="list-style-type: none"> <li>■ Inconsistencies in temperature measurement <ul style="list-style-type: none"> <li>– Dirt in bore of thermocouple</li> <li>– Tip of thermocouple not in contact with metal surface</li> <li>– Problems with thermocouple and/or recording device (e.g., thermocouple damaged)</li> </ul> </li> </ul>



**Figure 2:** Design of a three-zone screw for processing of TROGAMID by extrusion

Lighting system of TROGAMID CX



# Fabricating

## 5 Fabricating and Finishing of Molded Parts and Semi-Finished Products

<b>Bonding</b>	
General information	<ul style="list-style-type: none"> <li>■ Adherent surfaces must be clean.</li> <li>■ Avoid the use of mold release agents when manufacturing parts to be bonded.</li> </ul>
Adhesives	<ul style="list-style-type: none"> <li>■ Commercially available adhesives based on:               <ul style="list-style-type: none"> <li>– Polyurethanes: one- or two-pack and (reactive) hot melt adhesives (gap filling, flexible adhesives mostly with longer pot life and clamping time), suitable for larger adherent surfaces.</li> <li>– Cyanoacrylates: one-pack adhesives (short setting time), suitable for small gluelines and adherent surfaces.</li> <li>– Formic acid: diffusion bonding at room or elevated temperature.</li> <li>– Epoxies: one- or two-pack adhesives (gap filling), better results at elevated temperatures.</li> </ul> </li> </ul>
Pretreatment	<ul style="list-style-type: none"> <li>■ Improvement of bonding strength by a pretreatment of the surface to be bonded, e.g., by use of primers, roughening, electrical discharge, chemical treatment or flame treatment. Follow safety instructions at all times, especially when using primers and chemical treatment.</li> </ul>
<b>Machining</b>	
General information	<ul style="list-style-type: none"> <li>■ Sawing, turning, milling, drilling, and planing of TROGAMID parts is possible.</li> <li>■ Use of cooling fluids or compressed air recommended to prevent the TROGAMID parts from heating up and thus to avoid problems with sticking.</li> </ul>
<b>Printing and painting</b>	
General information	<ul style="list-style-type: none"> <li>■ Resin modifications for laser printing are available.</li> </ul>
Inks and paints	<ul style="list-style-type: none"> <li>■ For sublimation colors most kinds of inks possible.</li> <li>■ Screen printing colors must be modified for application on TROGAMID parts.</li> </ul>
Pre- and posttreatment	<ul style="list-style-type: none"> <li>■ Surface treatment, e.g., by electrical discharge, flame treatment or bristling very often lead to an improvement of the adhesion of the ink.</li> <li>■ After printing the adhesion of the ink can be improved, e.g., by annealing or flame treatment.</li> </ul>
<b>Welding</b>	
General information	<ul style="list-style-type: none"> <li>■ All established types of welding technologies can be applied on TROGAMID; typical technologies used are:               <ul style="list-style-type: none"> <li>– Hot plate welding: use PTFE-coated hot plate welding tools to avoid/reduce sticking of the resin at temperatures up to 270 °C</li> <li>– Ultrasonic welding: joint design like a triangular projection (called an energy director) or like a shear joint</li> <li>– Friction welding by rotation (spin welding) or vibration</li> <li>– High-frequency welding</li> </ul> </li> </ul>

Seal rings for battery cells of TROGAMID T





This information is based on our present knowledge and experience. However, it implies no liability or other legal responsibility on our part, including with regard to existing third party patent rights. In particular, no guarantee of properties in the legal sense is implied. We reserve the right to make any changes according to technological process or further developments. The customer is not released from the obligation to conduct careful inspection and testing of incoming goods. Reference to trade names used by other companies is neither a recommendation, nor is it intended to suggest that similar products could not be used. All our business transaction shall be exclusively governed by our General Sales Conditions.

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