Introduction

General information

VESTAMID® molding compounds are processed in the form of granules for extrusion and injection molding. Most standard processing machines, such as those for PE or PP, are suitable for this purpose. We recommend that you follow the instructions below.

Drying

VESTAMID® molding compounds are supplied as granules in moisture-proof packages of capacity 25 kg (11.3 lb). We can supply VESTAMID® in octabins of 1000 kg (453 lb) capacity upon request. The molding compounds can be processed straight from a newly opened package without further pre-drying. The product can be stored for at least two years in the closed and undamaged original packaging, in dry rooms, and under typical storage conditions at a temperature no higher than +30°C (90°F). Do not allow the storage temperature to become any warmer, particularly for plasticized molding compounds (e.g., VESTAMID NRG 1001).

Before opening a package, you should allow its contents to reach the ambient temperature so that moisture in the air has no chance to condense on the granules. Because VESTAMID® granules slowly absorb moisture, tightly reseal any opened bags that have not been emptied. Fill the feed hopper of the processing machine only with as much granulate as is processable in about two hours. Close the hopper with a cover plate.

You should dry the granules only if the packaging has been damaged or has been left open for more than two hours. In such cases dry the molding compounds until the water content returns to a level less than 0.1%. If the molding compound contains too much moisture, you will encounter processing problems, bubble formation, and poor moldings properties. The molding compounds possess good temperature stability, but avoid excessive drying anyway. You will notice this in extrusion when the melt becomes discolored and forms a slightly grainy, crumbly surface.

Recommended drying conditions for VESTAMID® molding compounds

<table>
<thead>
<tr>
<th>VESTAMID® grade</th>
<th>Drying temperature (°C) / (°F)</th>
<th>Drying time [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry-air dryer</td>
<td>Circulating air drying oven</td>
</tr>
<tr>
<td>PA121</td>
<td>80 – 100 / 175 – 210</td>
<td>2 – 4</td>
</tr>
<tr>
<td>PA12 plasticized2</td>
<td>80 / 175</td>
<td>2 – 4</td>
</tr>
<tr>
<td>PA612</td>
<td>80 – 100 / 175 – 210</td>
<td>2 – 4</td>
</tr>
<tr>
<td>PA612 plasticized3</td>
<td>80 / 175</td>
<td>2 – 4</td>
</tr>
</tbody>
</table>

1 Vestamid NRG 1002, 1003, 2101, 2901, 3001, 4101, 4901
2 Vestamid NRG 1001, 1004
3 Vestamid NRG 1905
Incompatibility with other thermoplastics

VESTAMID is incompatible with most other plastics, including other polyamides. Molding compounds based on PA 11 and PA 12, even VESTAMID® PA 12 and PA 612, are not mutually compatible. Limited compatibility exists only between the PA 12 molding compounds and the PA 12 elastomers. VESTAMID® molded parts that contain traces of another polymer generally exhibit poorer mechanical, thermal, and even chemical properties. In particular, contamination with foreign material reduces strength behind the mandrels or the mandrel supports in extrusion and behind cores in injection molding. Therefore, carefully clean the processing machine before starting production.

Coloring of VESTAMID®

We supply VESTAMID® molding compounds in a series of standard colors, and we can blend special colors for you on request.

VESTAMID® molding compounds can be colored during processing, too. In this case, use masterbatches based on PA 12 for PA12 or PEBA molding compounds, and on PA 612 for PA 612 molding compounds as your choice. Dry coloring with finely powdered colorants is feasible only when the granules are not pneumatically conveyed, because dust formation may otherwise occur.

If you use color pastes based on other polymers such as polyethylene, you may achieve incompatibilities with the VESTAMID® molding compounds and ultimately poor properties (low weld–line strength or poor low–temperature impact strength) of the molded part. It is absolutely essential that you be sure of the compatibility of the color paste before using it.

Processing of VESTAMID® molding compounds

In general, when processing thermoplastics, take care to ensure that the production hall is adequately ventilated. Mount an additional exhaust system over the machine nozzle; this is particularly important when processing molding compounds containing plasticizers or flame retardants.

Excessively high processing temperatures may decompose the materials; this may also happen when you clean polymer residues from screws and molds (with a burner). This will generate small amounts of volatile hazardous substances. Use thermal cleaning on system components, such as screws and molds, by burn–off. Do this with a suitable exhaust system. Follow the additional instructions in the safety data sheet.
Pipe extrusion

General information

Screw and extruder design

- The length of the screw for extrusion molding compounds (1–3) should basically always exceed 23 D.
- Typical three–zone screws with a compression ratio of 2.5:1 to 3.5:1 may be used.
- Possible ratios of the feed, compression, and metering zones: 2:1:3, 1:1:1
- Radial clearance between screw and barrel: 0.1–0.2 mm (4 mil–7.8 mil)
- The use of mixing and shearing elements improves melt homogeneity (e.g., for in–house coloring with colorant powder or concentrate).

For further information see figure of three–zone screw.

Note: Other screw designs (barrier screws, etc.) that give good processing results may also be used. Please contact us if you have any questions.

Design of a three–zone screw

Breaker plate

- A breaker plate for processing regrind or if screen packs are being used. Avoid elevated melt pressures, or else you will run the risk of the material degrading.

Gear pump

- Recommended for processing of regrind, or when it is absolutely essential to maintaining a low tolerance in the extrudate
- Generally not necessary for well–designed screws

Temperature settings

- To ensure an even flow of granulate, you should cool the feed zone of the extruder when using plasticized molding compounds. Excessive cooling, however, can lead to a very high (initial) torque of the screw, particularly for molding compounds for plasticizer–free large–diameter pipes. It is therefore particularly effective to temperature–control the feed zone in a way that is commensurate with its design. Unlike standard VESTAMID extrusion molding compounds (e.g., VESTAMID L2140 and L2124), even temperatures above 100°C (210°F) are possible as long as granulate transport in the screw is assured.
- The precise temperature settings (see table) depend on the type and size of the extrudate (film, profile, pipe, etc.), the design of the extruder, and the molding compound used. In general, therefore, it is difficult to set the exact temperature. As a general rule, the temperatures in the first heating zones of the extruder should normally be approximately 10 K above the melt temperature of the molding compound. At high torques of the screw, as in some barrier screws, or at low flow rates, barrel temperatures behind the feed zone of approximately 260°C (500°F) are entirely possible.
- To increase melt rigidity, it is advantageous to reduce the temperatures in the adaptor, mold, and nozzle heating zones.
Temperature setting

<table>
<thead>
<tr>
<th>Metering zone</th>
<th>Compression zone</th>
<th>Feed zone</th>
<th>Hopper area</th>
</tr>
</thead>
<tbody>
<tr>
<td>200°C – 280°C</td>
<td>200°C – 260°C</td>
<td>120° – 220°C</td>
<td>20°C – 220°C</td>
</tr>
</tbody>
</table>

Temperature setting for PA 12

<table>
<thead>
<tr>
<th>VESTAMID®</th>
<th>Barrel or melt temperature (°C) / [°F]</th>
<th>Mold temperature (°C) / [°F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA 612 plasticized³</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Optimization is possible by monitoring the temperature settings of heating bands and the melt temperatures, and from the melt consistency:
  - high build-up of pressure and matt surface of the melt: Increase the temperature profile.
  - low melt stability: Reduce the temperature profile.

Fairly large deviations between the set and the measured temperatures indicate that the screw is not optimally designed for VESTAMID® processing.

The temperature settings in all the heating zones should be at least 10 K above the melt temperature to prevent freezing.

Cleaning

1) Increase the temperature of all heating zones by 20 K and purge with PP (MFI 230/5 ≈ 12 g/10 min)
2) Disassemble the mold
3) Continue to purge with PP and reduce the temperature to approximately 170°C (335°F)
4) Replace the PP with a purging mixture of heat-stabilized PVC / cleaning liquid / glass fibers (in the ratio 98:1:1). Use only highly stabilized PVC, or else hydrochloric acid (HCl) will be released. Hydrogen chloride is corrosive and, in high concentrations, toxic. Inhalation may irritate the mucous membranes and the respiratory tract, which may lead to acute bronchitis or pneumonia. In case of contact with skin or clothing, the acid can be easily and thoroughly washed out with water. HCl also promotes corrosion of the mold and machines.
5) Pull out the screw and remove any residues adhering to screw or barrel.
6) Remove polymer residues from the mold, and then polish it.

1 Vestamid NRG 1002, 1003, 2101, 2901, 3001, 4101, 4901
2 Vestamid NRG 1001, 1004
3 Vestamid NRG 1905
Troubleshooting

- Pulsation of melt caused by the extruder
  - Excessively high temperature in the feed zone
  - Insufficient lubrication of the granulate
  - Inhomogeneous granulate form (if, for example, regrind is used)
  - Pressure build-up in mold too low
  - Unsuitable feed zone (grooved/smooth)
  - Unsuitable screw design
  - Problems with motor/gear unit
  - Temperatures in the metering zone, adapter region, or mold are too low.

Note: Pulsation of the melt can also be caused by one or more components of the downstream equipment (see also Troubleshooting for pipe extrusion).

- Inconsistencies in temperature measurement
  - Dirt in the hole of the temperature sensor
  - Tip of the temperature sensor not in contact with the metal
  - Problems in transmission of the measured values (due, for example, to a defective temperature sensor)

Mold

- Conventional mold designs (such as spiral mandrel systems) are recommended for production of monowall pipes.
- Draw down ratio (corresponds to the mean mold diameter divided by the mean pipe diameter): For smaller diameters, approximately 2:1 to 1.7:1; for larger diameters (> 60 mm or 2.3 inches) approximately 1.5 :1 to 1.1:1. Thin-walled pipes for relining applications are exceptions to this rule, usually being extruded with larger draw down and wall thickness ratios. The wall thickness ratio is the mold gap width divided by the thickness of the pipe. It is usually chosen so as to be approximately equal to the draw down ratio.
- The extrusion line is fitted with an exhaust system at the mold to extract vapors emitted by the melt.

Sizing

- Sizing tubes are usually used, and less often, sizing disks. On systems previously used for PE extrusion, adjustable sizing shows clear advantages if, in addition, PA12 pipes are being produced with the sizing unit.
- Choose the internal diameter of the sizing so that it is approximately 2 to 4% larger than the nominal diameter of the pipe. (Post)-shrinkage of PA 12 is less than that of PE. The use of sizings typically used for PE can therefore lead to larger external diameters of the pipes.
- The sizing inlet should be evenly covered with a water film, particularly at higher extrusion speeds, to pre–quench the melt entering the sizing. This prevents adhesion of the melt to the surface of the sizing, which could result in stick–slip effects.

Flame treatment

- To be applied to improve adhesion of printing.
- One–sided flame treatment can lead to pipe deformation comparable with that caused by a radial wall–thickness difference in production.

Haul–off and cutting unit

- You can use conventional haul–off units such as those employed in polyolefin processing here.
- Similarly, for cutting of the pipes, conventional cutting units like those in polyolefin extrusion can be used. This could give the internal edge of the cutting surface a slight white coloration; this is not material damage but merely a visual effect.
Troubleshooting

Surface quality
- Matt surface
  - Melt temperature too low
  - Non-uniform water flow at sizing inlet
  - Contamination of melt by foreign matter
- Streaks on the outer surface
  - Holes in the guide discs of the vacuum tank too small
  - Non-uniform water flow at sizing inlet
  - Mold damaged
  - Sizing damaged
  - Contamination of melt by foreign matter
- Bubbles on the outer surface
  - Moisture content of granulate too high
  - Vacuum too high
  - Water splashed on to the surface of the melt, due to excessively high water flow at the sizing inlet
  - Water droplets on the pipe surface at the inlet into the flame treatment unit
  - Large air bubbles in the vacuum tank could affect the pipe surface if the water tank is full
- Wave structure on the outer and/or inner surface of the pipe
  - Vibration of components of the extrusion line (e.g., cutter, puller ...)
  - Holes in the guide discs too small
  - The parallel zone of the nozzle is too short.
  - Use a spiral mandrel mold.
  - Haul-off speed too small when using a disc-type sizing
- Uneven pipe surface
  - Draw down and/or wall thickness ratio too small or too large
  - Sloshing of water in the vacuum tank

Pipe geometry
- Oval pipe
  - Vacuum too small
  - Distance between belts of puller too small
  - Pipe too hot when wound into a coil
- Uneven wall thickness
  - Mold not centered
  - Uneven water flow at sizing inlet
- Pipe is twisted during production
  - Uneven water flow at sizing inlet
  - Puller not correctly aligned in relation to the other system components
- Curved pipe
  - Uneven distribution of wall thickness
  - Uneven water flow at sizing inlet
  - Flame treatment from one side only
  - Faulty alignment of mold and sizing unit
  - Pipe too hot when wound into a coil

Mechanical properties of the pipe
- Elongation at break is too low
  - Vacuum too high
  - Sharp edges in the sizing unit, or radius of sizing inlet too small
  - Uneven water flow at sizing inlet
  - Melt temperature too low
  - Flame treatment from one side only
  - Faulty alignment of mold and sizing
  - Contamination of the melt with foreign matter, dirt, dust, etc.
  - Degradation of the molding compound
• Low-temperature impact strength inadequate
  - Contamination of the melt with foreign matter, dirt, dust, etc.
  - Melt temperature too low
• Splitting of pipe
  - Melt temperature too low
  - Contamination in the weld lines

**Injection molding**

**Plasticizing unit**

**Screw and barrel**
- Three-zone screw with a length of 18 to 22 D
- Flight depth ratio ≥ 2
- Minimum flight depth: 2 mm (0.07 inch) in the metering zone, 4 mm (0.15 inch) in the feed zone
- Screw diameter and barrel diameter should be so chosen that a metering stroke of 1 D to 3 D can be realized.

For further information see figure of three-zone screw on p. 3.

**Peripheral screw speed**
- Optimal setting in the range 3–12 m/min (120–470 inch/min)
- Higher speeds (e.g., greater than 18 m/min (798 inch/min)) are possible but may lead to problems in processing.

**Nozzle**
- In general, open nozzles are better. For molding compounds of low viscosity (e.g., VESTAMID® L1670, VESTAMID® L1723) externally operated shut-off nozzles (e.g., needle valve nozzles) are recommended.
- The bore of the nozzle should be approximately 0.5 to 1 mm (20–40 mil) smaller than the gate.

**Non-return valve**
- Clearance between non-return valve and barrel ≤ 0.02 mm (0.78 mil)

**Cleaning**
- For slight contamination (e.g., during product change)
  1) Prepare a mixture of high-viscosity PP and PLEXIFIX cleaning granulate (from Evonik) in the ratio 2:1
  2) Increase the temperature settings of the heating zones by 30 to 40 K, but not beyond 300°C (570°F)
  3) Plasticize the mixture with a long metering stroke and high dynamic pressure and then
  4) Discharge into the atmosphere at high speed.
- Persistent contamination
  - Can usually be removed only by mechanical cleaning of the screw, barrel, non-return valve, etc.
  - In some cases it may be possible to avoid mechanical cleaning by using special cleaning agents such as RAPID PURGE (Rapidpruge.com), SUPERNOVA (from Engineering Chemicals), or ASACLEAN (from Velox).

**Clamping unit**

**Clamping force**
- A guide value for the cavity pressure in the processing of VESTAMID® is 2002600 bar (2900–8700 psi).
Mold
Gate
- All conventional sprues, runners, and gates may be used.
- Diameter and thickness of the pin, tunnel, and film gates $\geq 0.6 \text{ mm (23.6 mil)}$

Hot runner
- Externally heated hot runner systems with open sprue nozzles, diameter $\geq 0.6 \text{ mm (23.6 mil)}$, are recommended.

Venting
- Vent slots in the mold parting line, 0.01–0.03 mm (0.4–1.18 mil) high, 4–5 mm (157–196 mil) wide

Mold steel
Suitable steel grades include 1.2767 (X45NiCrMo4), 1.2379 (X155CrVMo121), 1.2312 (40CrMnMo58), and 1.2343 (X38CrMoV51).
Design of a three-zone screw

Pressure sensor
- for accurate setting of the changeover point. The use of a pressure sensor for the cavity pressure is recommended.

Mold release
- In general, an additional mold release agent is not necessary.
- Reduction of the mold temperature very often facilitates mold release.
- Ni–P–PTFE and TiAlOx have proven useful in practice for coating of the mold surface.

Processing conditions
Temperatures
- For general information on temperature settings, see the following tables.
- Temperature settings at the nozzle and at the heating zones near the nozzle are at the same level as the melt temperature; for non-reinforced molding compounds and the use of open nozzles, temperatures about 10 K lower may be advantageous.
- A temperature profile decreasing in steps of 10 K toward the hopper is recommended.
- The temperature in the feed zone should be between 40 and 80°C (100–175°F).

Interruption of production
- For brief interruptions of production (of up to an hour), empty the plasticizing unit, move the screw as far forward as possible, and reduce the temperature to 150°C (300°F).
- For longer interruptions of production, first purge with PP or PMMA, then empty the plasticizing unit and move the screw as far forward as possible. Switch off the barrel heating. Remove any material remaining in the hopper and store in moisture-proof packaging.
Recommendations for melt and mold temperature for PA 12 and PA 612

<table>
<thead>
<tr>
<th>VESTAMID*</th>
<th>Melt temperature (°C) / (°F)</th>
<th>Mold temperature (°C) / (°F)</th>
<th>Drying temperature (°C) / (°F)</th>
<th>Drying time* (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA 12(^1) plasticized</td>
<td>230 – 290 445 – 555</td>
<td>60 – 100 140 – 210</td>
<td>80 175</td>
<td>2–4</td>
</tr>
<tr>
<td>PA 12(^2)</td>
<td>230 – 290 445 – 555</td>
<td>60 – 100 140 – 210</td>
<td>80 – 110 175 – 230</td>
<td>2–4</td>
</tr>
<tr>
<td>PA 612 plasticized(^3)</td>
<td>230 – 270 445 – 520</td>
<td>60 – 100 140 – 210</td>
<td>80 – 110 175 – 230</td>
<td>2–4</td>
</tr>
</tbody>
</table>

* Dry-air dryer

Fabricating and finishing of molded parts and semi-finished products

Welding

Heating element butt welding
- See SKZ
- See DVS
- See Kiwa Gastec

Bonding

The surfaces to be bonded should be clean and free of grease. The use of mold release agents is not recommended in the fabrication of molded parts that are to be bonded.

Adhesives

Conventional adhesives based on
- Epoxide: single- or two-component adhesives (gap-filling); suitable for relatively large bonding surfaces; better results often obtained at higher temperatures.
- Polyurethane: reactive single- or two-component adhesives and hot-melt adhesives (gap-filling, flexible adhesives, often with fairly long pot life and curing time); suitable for relatively large bonding surfaces.
- Cyanoacrylate: single-component adhesives (with very short curing times); suitable for thin bonded joints and relatively small bonding surfaces.

Pretreatment

Adhesive strength can be improved by pretreatment of the surfaces such as roughening, use of primers, corona discharge, and flame treatment. The relevant safety instructions must be observed.

Machining

VESTAMID® molded parts can be sawed, turned, drilled, or milled. To prevent molded parts from adhering to one another and to protect against heat build-up, we recommend additional cooling during machining.

Printing and painting

Laser marking
- Laser-markable VESTAMID® molding compounds are available.

Paints and printing inks
- Most printing inks can be used for dye sublimation printing.
- Screen inks must be adapted for use with VESTAMID® molding compounds.

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1 Vestamid NRG 1002, 1003, 2101, 2901, 3001, 4101, 4901
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