Processing VESTAMID® HT*plus*

Injection Molding

General Information

VESTAMID® HT*plus* PPA compounds are processed, for injection molding purposes, mainly in the form of granules. Most standard screw-type injection molding machines are suitable. The plasticizing unit should be dimensioned for HT thermoplastics, with processing temperatures up to 400°C, although it may be necessary to modify hardware and software. We also recommend that you follow the information about PPA injection molding in this flyer.

We also offer extensive technical service that is dedicated to finding technically sophisticated system solutions together with our customers. This includes support with simulation calculations for developing tools and molds.

For more details, please ask your local contact person.

Contents

Drying

PPA leaves the plant with a moisture content of less than 0.10 % by weight. To obtain high-quality molded parts, however, you should allow for additional drying in a dehumidified air drying oven.

Drying temperature:	+120°C
Drying time:	4h in dehumidified air drying oven
Max. residual moisture:	Recommendation less than 0.06%

Information:

- The dew point of the dryer should be less than -30°C.
- We recommend to use dry air for granulate conveying.
- Air throughput: ~ 2.2m³/h/kg (Source: Motan, drying diagram see Fig. 1)

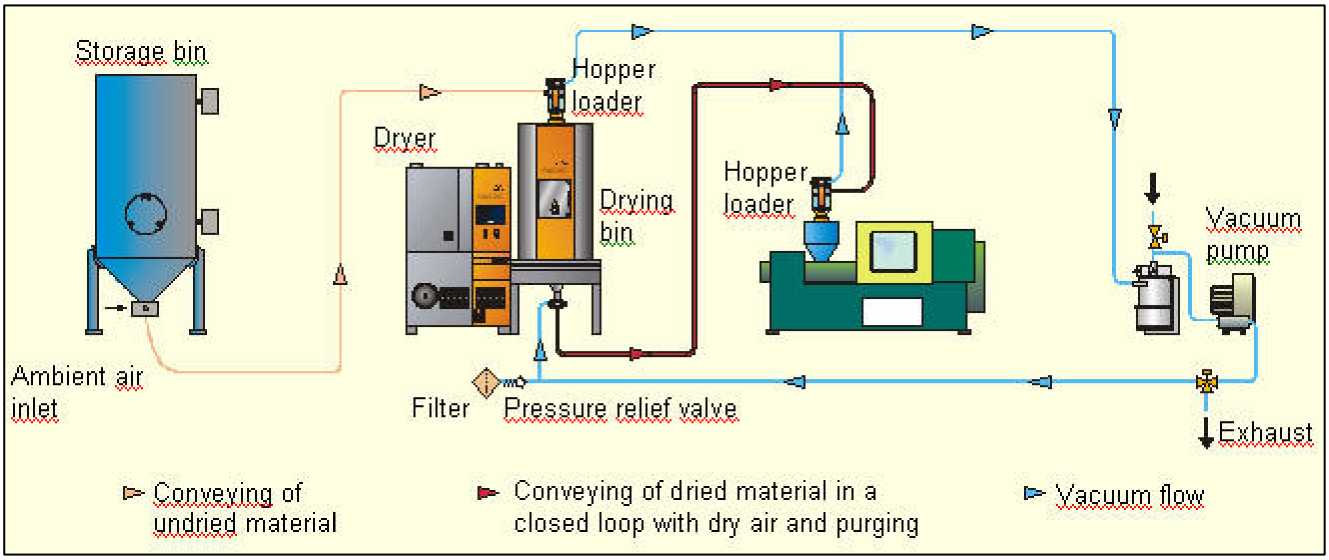


Fig.1: Drying diagram for PPA (Motan)

Plasticizing unit

Screw and cylinder

A length of 20 to 22 D is suitable for processing PPA.

- Zone distribution: Intake 50-60%, compression 20-25%, metering 20-25%
- Compression ratio 2.5-3.5:1

Size of the plasticizing unit: Required metering volume is between 30% and 70% of the maximum possible shot volume. This achieves a homogeneous melt quality and prevents from air intake. (Fig. 2)

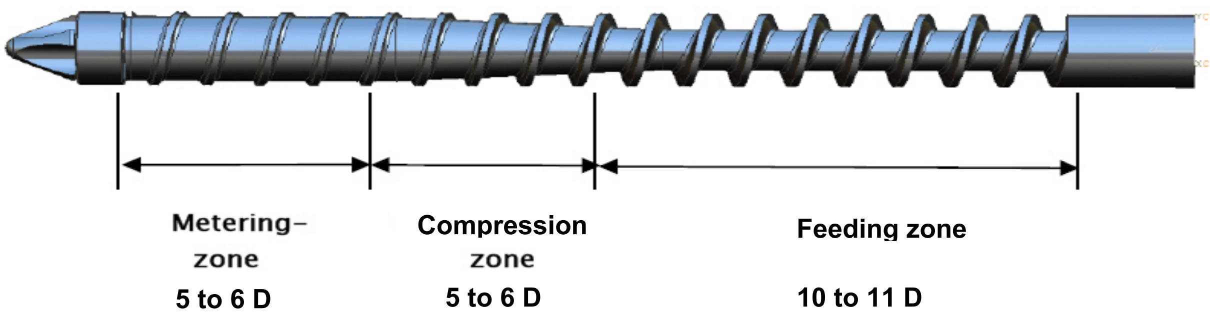


Fig. 2: Universal 3-zone screw

Backflow valve

Conventional three-part backflow valve are used. Machine manufacturers offer a wide range of these devices in various designs. It is crucial to have reproducible, quick backflow valves during injection so that the molded parts of consistent quality and weight can be obtained. Therefore, the backflow valve should be inspected regularly.

Machine nozzle

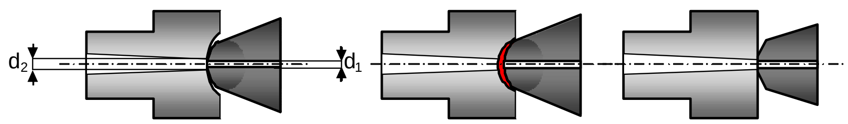
Open nozzles are mainly used. A low decompression of approximately 3 to 5 mm prevents melt escaping from the nozzle bore. If the decompression stroke is too long, however, this causes air to become entrapped and leads to burning near the sprue.

Shut-off nozzles (pneumatically or hydraulically operated) are also used; however, depending on the design, additional losses in injection pressure may have to be taken into account because of the less favorable melt feed. Shut-off nozzles prevent the melt from escaping from the injection cylinder and can prevent the formation of threads. The pneumatic systems generally work with compressed air connections between 5 and 10 bar, while hydraulic shut-off nozzles need between 40 and 70 bar hydraulic pressure. In existing "dead corners" thermal damage can occur due to long dwell times.

For all types of nozzle, ensure that adequate heating is used. To prevent nozzle freezing or the formation of a cold slug on the sprue bushing with an adjacent injection unit, ensure that the heater band is covered the entire length of the nozzle body.

For easy sprue gate demolding, the output diameter (d_1) of the machine nozzle should be approximately 0.5 to 1 mm smaller than the bore diameter (d_2) of the sprue bushing. Make sure, too, that the radius of the machine nozzle is smaller than the radius of the sprue bushing (e.g., nozzle radius = 35 mm, sprue bushing radius = 40 mm).
(Fig.3)

Fig. 3: Coordinating the radii of machine nozzle and sprue bushing



Favorable combination	Unfavorable combination	Favorable combination
Machine radius less than tool radius, produces good sealing without material escaping and good demolding of sprue gate	Machine radius greater than tool radius, inadequate sealing with material escaping and poor demolding of the sprue gate	With flat nozzles the bearing surface should be as small as possible and only as large as necessary

Injection unit

Processing VESTAMID® HT*plus* in an injection cylinder usually involves using screws made from corrosion and wear-protected PM steels. We recommend bimetallic equipment for the injection cylinder.

Dwell time

To prevent thermal degradation of the melt, do not allow the dwell time in the injection cylinder to exceed approximately 6 min.

Cleaning

General

Before you work with VESTAMID® HT*plus,* you must completely remove other polymers from the plasticizing unit. This is done either by mechanically cleaning the cylinder and screw or by using suitable cleaning materials (e.g., Rapid Purge, Asaclean). A highly viscous PP with an MFI less than1g/10 min has proved to be a suitable polymer.

Cleaning when starting the injection molding machine

1. Set the cylinder temperature to values at which the material to be removed is normally processed.
2. Introduce the cleaning material and purge until there are no traces of the material to be removed.
3. Operate the screw until it is empty.
4. Adjust the cylinder temperatures to the values required for working with PPA.
5. When the temperatures are reached, switch to PPA and feed material until the melt is clean.

Cleaning when shutting the injection molding machine down

1. Interrupt the material feed from the funnel to the injection molding machine.
2. Operate the screw until there is no more PPA in the injection unit.
3. Introduce the cleaning material and continue extruding until there is no more trace of PPA.
4. Reduce the cylinder temperatures to a level that is still acceptable for PPA (320°C).
5. Continue purging with the cleaning material until the cylinder temperature has fallen to the level required for the following material (Assumption: lower processing temperature).
6. Meter the following polymer or switch off heating if the machine is to be shut down.

Clamping unit

Clamping force

The required clamping force depends on the size of the planned injection surface (surface of the sprue and the molded part) and the resulting pressure inside the mold. The clamping force must be adequate to prevent tool breathing and over-packing of the mold.

Tools

Tool steel

For the mold cavity, steel types with adequate hardness (approx. 50 to 54 HRC) to withstand the high processing temperatures should be used. Table I lists the most commonly used cast steel alloys. If high thermal conductivity is an issue, mold inserts made from copper-beryllium can be used on which protective layers of chromium and nickel can also be applied.

Tab. 1: Tool steel types and thermal conductivity of steel and copper alloys for injection molding tools (selection)

Name	Thermal conductivity [W/m*K]	Density [g/cm³]	Application
Steel 1.2083	24	7.85	Corrosion-resistant hot-forming tool steel with HRC 50 to 54 for chemically aggressive polymers, good polishing properties with high wear resistance, good machinability, polymers containing flame retardants
Steel 1.2316	24	7.85	Corrosion-resistant tool steel, good polishing properties, can be hardened to approximately 52 HRC for SG molds and inserts, can be coated with PVD and can also be chrome plated, polymers containing flame retardants
Steel 1.2343	25	7.85	Hot-forming tool steel with good polishing and nitriding properties with insert hardnesses up to 50 HRC for applications subject to abrasion, can be coated with PVD and can also be chrome-plated
Steel 1.2379	21	7.70	Hardened tool steel with hardnesses up to 62 HRC for inserts subject to abrasion, high wear resistance, for reinforced molding compounds
Amcoloy 83 (Ampco Metal Cu-Be alloy) 2.1247	106	8.26	Applications with high thermal stress with good thermal conductivity, insert temperatures of up to 300°C, while still retaining its mech. properties. Various surface coatings (WC/C, CrN) possible. Chemical nickel application is recommended.
Moldmax HH (Cu-Be alloy Uddeholm) 2.1247	105	8.35	Cores in steel molds with high thermal conductivity, approximately 4 times higher thermal conductivity than steel, can be used at temperatures up to 300°C
Copper	393	8.95	

Sprue

Minimum diameter of the sprue gate: approximately 4 mm, the minimum input diameter is 1.5 times the largest thickness of a molded part.
Sprue angle: from experience, between 1° and 3° to enable easy demolding of the sprue gate.
Ejector claw: especially for sprue gates

Sprue manifold

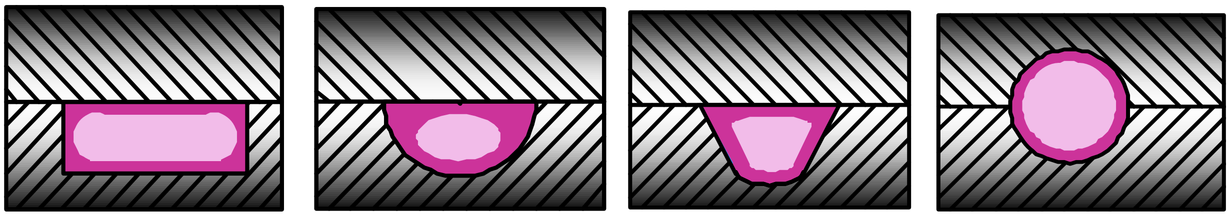
Sprue manifolds should be round or trapezoid (see Figs. 4, c and d) (as large a flow cross-section as possible with the smallest surface as possible). Semi-round or rectangular manifold geometries (see Fig. 4, a and b) are not recommended.

Gate, gate systems

The gate system depends on the volume of melt, the number of mold cavities, and the geometry of the molded part. Almost all conventional systems can be used; however, small tunnel gates freeze quickly and are more suitable for short holding pressure times and thin walls.

The gate should be positioned to prevent jetting because this usually leads to weak points as caused by weld lines and surface defects. By connecting it to the thickest part of a wall it is possible to reduce, or even completely prevent, undesired sink marks.

Fig. 4: Different cross-sections of sprue manifolds



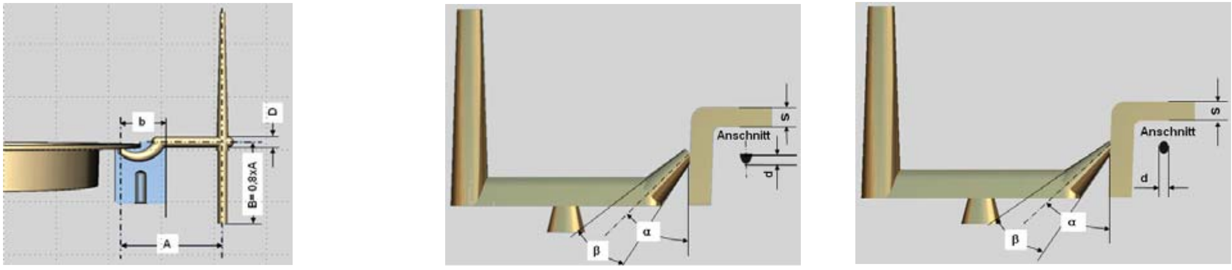
rectangular	semi-round	trapezoid	round
unfavorable	unfavorable	alternative to round cross-section	smallest surface in relation to the cross-section
a	b	c	d

Tunnel gate

The tunnel gate shown in Fig. 5 can be used, although the gate variant with dead end recess in Fig. 5b solidifies slower and reduces pressure loss and shearing in contrast to the tunnel without dead end recess (Fig. 5c). This allows longer holding pressure times with better holding pressure transfer.

With VESTAMID® HT*plus* the manifold should be slightly larger than shown in table value A so that it can be ejected more flexibly during demolding. The underfloor gate shown in Fig. 5a can also be used.

Fig. 5: Various tunnel gate designs for VESTAMID® HT*plus*



Underfloor gate (a)	Tunnel with dead end recess (b)	Tunnel without dead end recess (c)
Example E1690 (see catalog from Meusburger): A = Table maximum value b = 15 mm→A= 34 mm, D= 2.5 mm b = 18 mm→A= 45 mm, D= 4 mm Gate area A for GF-filled VESTAMID HT*plus* should be increased by about 45%	for s ≤ 4 mm α = 30 (hard) to 50° (viscoelastic), β = 20–30°, d = 0.8 to 2 mm (normal), gate area A for GF-filled VESTAMID HT*plus* should be increased by about 45%	for s ≤ 4 mm α = 30 (hard) to 50° (viscoelastic), β = 10–20°, d = 0.8 to 2 mm (normal), gate area A for GF-filled VESTAMID HT*plus* should be increased by about 45%

Hot runner system

Nozzle designs heated from outside are especially suitable for processing VESTAMID® HT*plus* with hot runner systems (Fig. 6). These systems are characterized by low pressure losses and specifically favorable flow channel cross-sections. If colors are changed frequently, the best solution is to have a system heated externally without a pre-chamber, which offers advantages in terms of rinsing behavior within the melt channel. For the fastest possible color change times, the shearing speed in the channel should be between 700 and 1,300 1/sec. This can be achieved, for example, with a small melt channel diameter. The amount of pressure loss, however, must be considered and adequate filling of the mold must be ensured. So-called cleaning granules can also minimize color change problems; although these should be tested to ensure that they can be used in the hot runner.

You should especially make sure that there is good thermal separation between the hot runner and the injection molding tool. During start-up, a hot runner nozzle has been shown to be useful for filling the insulating gap with unfilled polymer because filled polymers (carbon or glass fiber) favor the undesired heat dissipation from the hot runner nozzle to the injection mold.

With reinforced VESTAMID® Ht*plus* grades hard metal heat conducting torpedoes offer adequate wear protection. With filler contents in excess of 20% the gate diameter should be 10–20% larger. However, if the gate is too large, this can cause bad cut-off quality because of inadmissibly high gate residues on the molded part.

Fig. 6: Hot runner nozzle, heated from outside (Günther)

Pin shut-off systems are also used, but are not recommended for compounds with fillers (e.g. glass fiber).

Generally, no special steel types are necessary for processing VESTAMID® HT*plus* in the hot runner. Often the corrosion-resistant tool steel 1.2316 with increased chromium content (15%–17%, see also Tab. 1) is used.

A properly designed gate geometry, which is recommended by the manufacturer, is a requirement for precise thermal separation between the hot runner nozzle and the tool cavity. To produce molded parts with high-quality surfaces and clean cut-off points, follow the manufacturer's installation and product recommendations. The hot runner that is used should guarantee temperature deviations of max. +/-1°C. A start-up circuit with sensor load recognition is state of the art and is also an advantage.

For pressure losses to be kept as low as possible, the gate openings should be generously dimensioned. Pressure losses in the hot runner can be calculated, based on material data, by many manufacturers of hot runners; the melt channel cross-section in the manifold and the hot runner nozzle are essentially dependent on the volumetric flow rate (shot weight), the number of color changes, and the dwell time. If sub-manifolds are used in the injection process, the gate diameter can be about 0.5 mm larger, which reduces the shear rate (friction) of the polymer melt.

Tab. 2: Guiding values for the dimension of hot runner nozzles in relation to the shot weight of the molded part (Source: Synventive)

Shot weight up to… [g]	Inlet diameter in the hot runner nozzle up to … [mm]	Outlet diameter of the hot runner nozzle in the cavity [mm]
10	4	0.8–1.75
150	7	1.0–2.7
1500	12	2.4–3.6
2500	16	2.4–3.9

Venting

Venting channels in the tool separation level or especially at the end of the flow channel can generally be integrated up to 0.015 mm deep without flashing. If necessary, it is possible to deepen this to 0.03 mm; however, flashing will be observed.

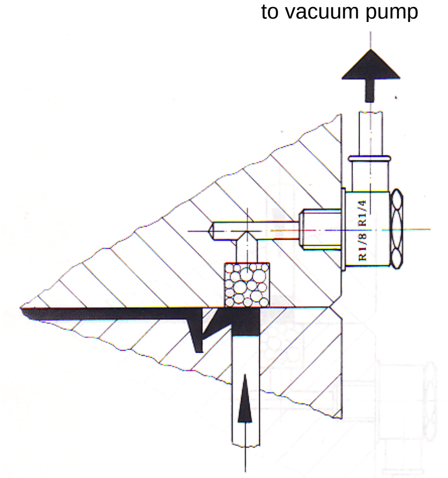


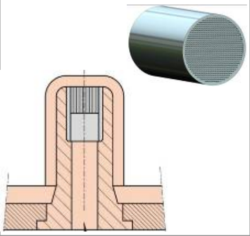
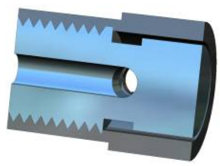
Fig. 7: Venting diagram (Bawema)

Tool venting with suitably machined ejector pins can also provide support.

Lamellar inserts at critical points, e.g., weld lines, can help to prevent burners and the formation of coatings on the mold surface. Compressed air in the cavity can reach tempera-tures of up to 1,300°C and damage the mold and cause corrosion problems on the wall of the tool. Especially in blind holes, sufficient venting must be ensured, since otherwise molded parts may not be completely filled. Venting pins offer some help and they can be removed easily for cleaning. Important is that the venting inserts are correctly positioned (Tab. 3), regular maintenance prevents the pores becoming blocked. Since venting elements are usually seen on the surface of the molded parts, be careful when calculating the position of the entrapped air. Another venting improvement can be achieved with a diagonal cut in both sides of the mold parting surface. In most cases, roughness of between 0.007 and 0.009 mm ensures adequate venting of the mold cavities.

If a vacuum is to be created in the mold cavity before the injection process, you should connect a vacuum pump (Fig. 7) to the intended venting inserts (sintered metal, annular gap, ejector pins). Usually the venting device is activated whit a switch activated during the closing process or directly via the machine control system. A time relay determines the duration of the evacuation. In case of contamination, the venting insert can be blown free with a counter air flow (approx. 5 to 6 bar). For a short evacuation time, the venting channels should be as short as possible. Both, a precise nozzle contact on the sprue gate and a dense tool design prevent extraneous air flowing in. A guiding value is a venting volume of 10 cm³ with 1 bar negative pressure and 90% vacuum when sintered metal plugs are used (Tab. 3), for example, typical venting times of 1 to approximately 5s. If venting valves are used, times of less than1s can be realized. (Source: BAWEMA)

Tab. 3: Contour-internal venting alternatives (Source: BAWEMA)

	Sintered metal plugs	Venting inserts	Lamellar inserts with thread	Venting valves
Inserts				
Material	Sintered metal, pores with undefined geometries (Strack)	Sintered metal venting inserts, very thin wires joined together, pore size 0.03 mm (DME)	Can be unscrewed from the front for cleaning, steel with 48 to 50 HRC, various diameters possible (Wema)	Surfaces ground in the degassing area, venting surface is the cross-section of the ring gap (DME)
Venting time of 10 cm³ at 1 bar negative pressure and 90% vacuum	3 to 5 s	approx. 1s	-	0.3 to 0.6 s

Drafts, roughness according to VDI 3400

Drafts (angles) must be planned for all inside and outside surfaces in the demolding direction. This is important to prevent damage to the mold during ejection. For VESTAMID® HT*plus,* an angle of approximately 0.5° to 1.5° should be considered.

The size of the draft x depends on the surface structure (roughness), the demolding path, the wall thickness, and the polymer being used. Especially where there are deep ribs if the draft is insufficient, there is a risk that the molded part can be damaged or deformed or have stretched areas when it is ejected.

To minimize the risk of damage during demolding of parts with structured surfaces, comply with the additional minimum drafts recommended in Tab. 4.

Pressure sensors

The use of an internal pressure sensor to accurately set the switching point is recommended if there are high demands in terms of constant weight and dimensional stability.

Tab. 4: Recommended draft in relation to roughness

VDI 3400 selection of classes	Roughness R_a [µm] Arithmetic average	Min. draft x [°] VESTAMID® HT*plus*
12 (fine)	0.40	1.0
15	0.56	1.0
18	0.80	1.2
21	1.12	1.2
24	1.60	1.5
27	2.24	1.5
30	3.15	1.8
33	4.50	2.0
36	6.30	2.5
39	9.00	3.0
42	12.50	4.0
45 (rough)	18.00	5.0

Temperature control

With the recommended tool surface temperatures of up to 180°C, you can work with both oil and water-operated temperature control systems; however, because of its higher thermal capacity and conductivity—depending on the temperature and Reynolds number—water can remove heat about twice as fast as oil. Be careful when choosing special hoses and connectors that are approved for the high temperatures. Solid screw-in joints are better for the inlet lines to the tools than plug-in or coupling systems. If plug-in connectors are used, the inside diameter should be larger than the transition points to avoid the reduction of the flow volume and not to cause additional pressure losses in the system.

The maximum permitted continuous use temperatures of all seals in the tool must also be considered (Viton® up to 200°C, Kalrez® up to 275°C); the same applies to the seals in the hydraulic cylinders with core pullers.

To minimize losses from heat radiation to the outside, you can cover the outer surfaces of the tool with insulation sheets. Use of heat insulating sheets (e.g. Z121, Hasco) between the machine bearer plates and the tool is recommended. Solids deposits, such as scale and rust, in the temperature control channels cause considerable heat transfer losses and can be avoided with preventive water treatment methods, such as softening and conditioning the water with suitable chemicals and by coating the inside of the temperature control channels with chemical nickel.

Table 5 contains guiding values to determine the heat output in relation to the weight of the tool, the heating time, and the temperature difference. The formula below can be used to get an approximate value:
Heating capacity [KW] = Weight [kg] x 0.5 (spec. heat capacity of steel) x ΔT / 3600 (heating time in s)

Tab. 5: Guiding values for heat output in relation to the weight of the mold

Tool weight [kg]	Heating capacity [KW] at 0.5 h heating time and ΔT=140°C
up to 100	3-6 kW
up to 1000	to approx. 40 kW

To fulfill the high quality requirements placed on the molded parts, ensure that the temperature is distributed evenly throughout the molding surface. Fig. 8 shows the calculated isotherm course of a favorable and an unfavorable arrangement of the temperature control channels.

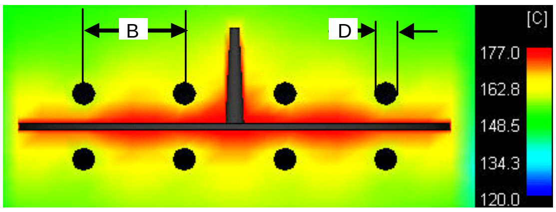
On the right side of Figure 8, the distances recommended in Tab. 6 (a, B and D) are complied with, while the left side shows an unfavorable arrangement because the bore is too near (dimension a) the wall of the cavity and was drilled with distance B too large. The circular isotherms shown in the simulation reduce the distortion tendency on the finished part.

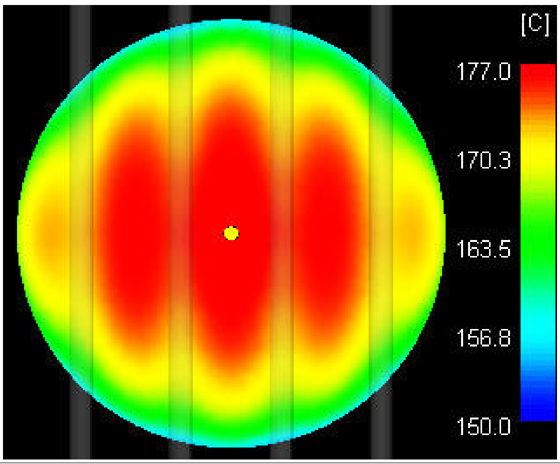
Tab. 6: Recommendations for diameter of and distances between temperature control channels (Source: GWK)

Wall thickness s [mm]	Distance between middle of the bore/molded part [a]	Distance between middle of the bore/middle of the bore [B]	Diameter of cooling bore [D]
up to 1.0	11.3–15.0	10.0–13.0	4.5–6.0
1.0–2.0	15.0–21.0	13.0–19.0	6.0–8.5
2.0–4.0	21.0–27.0	19.0–23.0	8.5–11.0
4.0–6.0	27.0–35.0	23.0–30.5	11.0–14.0
6.0–8.0	35.0–50.0	30.5–40.0	14.0–18.0

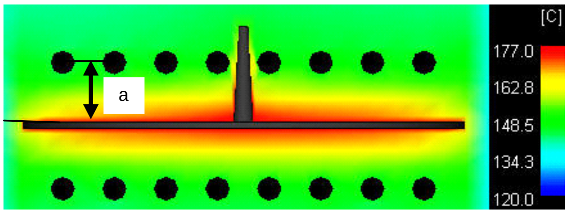
Fig. 8: Different arrangement of temperature control channels to the surface of the molded item

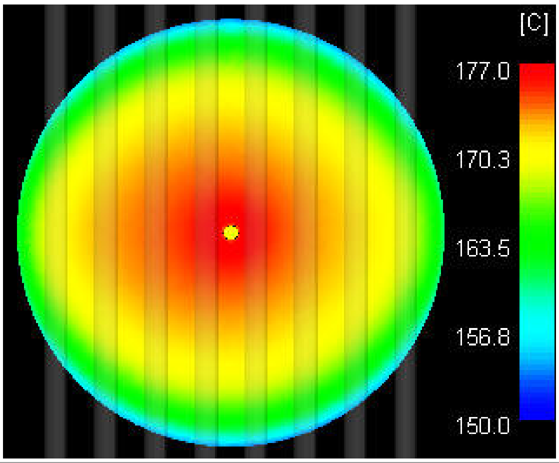
unfavorable arrangement





favorable arrangement





Example of an even sheet: wall thickness = 2.5 mm, tool temp.=180°C, compound temperature = 340°C

unfavorable arrangement	favorable arrangement
a = 12.5mm, B = 42mm, D = 10mm	a = 25mm, B = 21mm, D = 10mm
Inhomogeneous temperature distribution	Homogeneous temperature distribution

Shrinkage

Tab. 7: Processing shrinkage and total shrinkage of VESTAMID® HT*plus*

VESTAMID® HT*plus* (sheet 60x60x2mm³)		Cylinder/ tool temp. [°C]	Holding pressure [bar]	Processing shrinkage long. [%]	Processing shrinkage transverse [%]	Total shrinkage after 5 h/170 °C storage long. [%]	Total shrinkage after 5 h/170 °C storage transverse [%]
PA 6T/X	M1000	340/160	600	1.3	1.5	1.5	1.7
	M1900(FR)	340/160	600	1.3	1.6	1.4	1.8
PA 6T/X GF reinforced	M10315	340/160	600	0.6	0.9	0.7	1.0
	M1033 M1633 R1033	340/160	600	0.2	0.9	0.3	1.0
	M1933(FR)	340/160	600	0.2	0.9	0.2	1.0
	M10345 M1035 M1634 M1635 R1035	340/160	600	0.1	0.7	0.1	0.8
	M1036 M1636	340/160	600	<0.1	0.5	0.1	0.6
PA 10T/X	M3000	310/140	600	1.4	1.5	1.7	1.8
	M3033	310/140	600	0.3	0.8	0.4	1.0
	M3035	310/140	600	0.1	0.7	0.2	0.9

FR = with flame retardant

Processing conditions

For successful processing of VESTAMID® HT*plus*, we recommend the process temperatures below:

Tab. 8: Recommended processing temperatures

VESTAMID® HT*plus*	Glass transition temperature T_G [°C]	Melt temperature [°C]	Compound temperature [°C]	Drying [h/°C]	Tool temperature [°C]
M1000 (Base resin)	125	315	320–345	4/120	140–180
M1900 (FR)	125	315	320–330	4/120	140–180
M10315 (15% GF)	125	315	330–345	4/120	140–180
M1033 (30% GF)	125	315	330–345	4/120	140–180
M1533 (30% GF)	125	315	330–345	4/120	140–180
M1633 (30% GF)	125	315	330–345	4/120	140–180
M1933 (FR, 30% GF)	125	315	320–330	4/120	140–180
M1634 (40% GF)	125	315	320–330	4/120	140–180
M1035 (50% GF)	125	315	330–345	4/120	140–180
M1635 (50% GF)	125	315	330–345	4/120	140–180
M1036 (60% GF)	125	315	330–345	4/120	140–180
M1636 (60% GF)	125	315	330–345	4/120	140–180
M3000 (base resin)	125	285	300–330	4/120	140–160
M3033 (30% GF)	125	285	300–330	4/120	140–160
M3035 (50% GF)	125	285	300–330	4/120	140–160
R1033 (K&K)	125	315	330–345	4/120	140–180
R1133 (K&K)	125	315	330–345	4/120	140–180
R1035 (K&K)	125	315	330–345	4/120	140–180

*K&K = Plastic and rubber

The cylinder temperature profile should be set to a moderate increase, with the feed zone temperature 10 to 20°C lower than the final cylinder heating zone temperature.

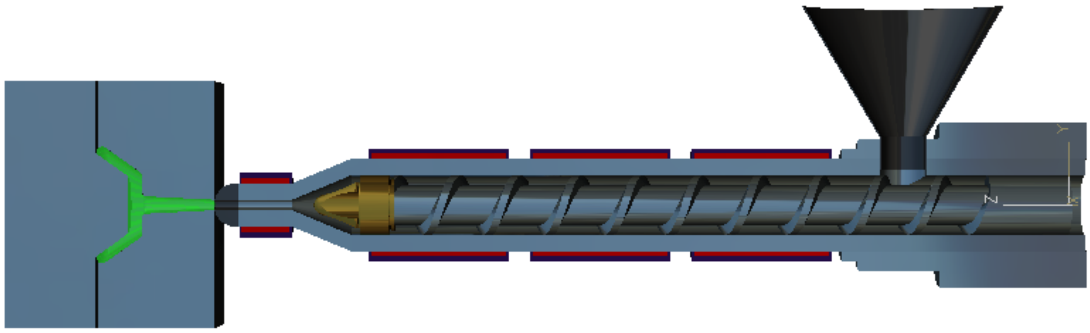
The optimum molding compound temperature depends on various factors, such as dwell time in the plasticizing cylinder and the tool and mold design (e.g., flow path/wall thickness ratio) of the molded part.

The temperatures for the molding compound and the melt indicated in Table 8 can be set as the initial temperatures. With short dwell times and thin walls, these can be increased by 5 to 10°C.

If the recommended temperatures are exceeded further, this can cause material damage and should be avoided. The melt temperatures can, for example, be checked by means of a probe thermometer in the melt.

If you are processing the flame-protected molding compounds VESTAMID® HT*plus* M1900 and VESTAMID® HT*plus* M1933, we recommend a maximum temperature of 335°C in the entire process chain and the use of corrosion and wear-resistant steel types.

Table 9 contains guiding values for the cylinder and tool temperatures.



Tab. 9: Guiding values for cylinder and tool temperatures

	Tool temperature [°C]	Nozzle [°C]	Zone 3 [°C]	Zone 2 [°C]	Zone 1 [°C]	Hopper [°C]
M1000 PA 6T/X not reinforced	140–180	320–340	320–340	310–330	300–320	40–100
M1033, M1035 PA 6T/X reinforced	140–180	330–345	330–345	320–340	310–330	40–100
M3000 PA 10T/X not reinforced	140–160	310–330	310–330	300–320	280–300	40–80
M3033, M3035 PA 10T/X reinforced	140–160	310–330	310–330	300–320	290–310	40–80

Screw speed, screw circumferential speed

Circumferential speed: less than 300 mm/sec
Example: Speed less than 190 rpm at 30 mm screw diameter

Higher circumferential speeds are not advisable, because with filled material this can damage the fibers and overload the melt due to large local shearing effects. The entire cooling time should be used in metering.

Back pressure

Back pressures of up to 5 MPa improve the homogeneity of the melt. For reinforced VESTAMID® HT*plus* grades, a low dynamic pressure is recommended for processing the fillers carefully and retaining the mechanical properties.

Decompression

Where the melt comes out of the open nozzle, a decompression path of approximately 3 to 5 mm is recommended.

Injection rate

The injection rate depends mainly on the design of the molded part and the length of the flow path.

The injection pressure limit should be set high enough so that a reproducible, controlled injection rate is achieved; in other words, the required injection pressure should be approximately 10% below the injection pressure limit. Accumulator machines are recommended for short filling times.

Injection pressure

The injection molding machine should be dimensioned to withstand injection pressures of at least 200 MPa, although the required injection pressure depends a lot on the melt and tool temperatures and on the ratio between the flow path and the wall thickness of the component.

Holding pressure

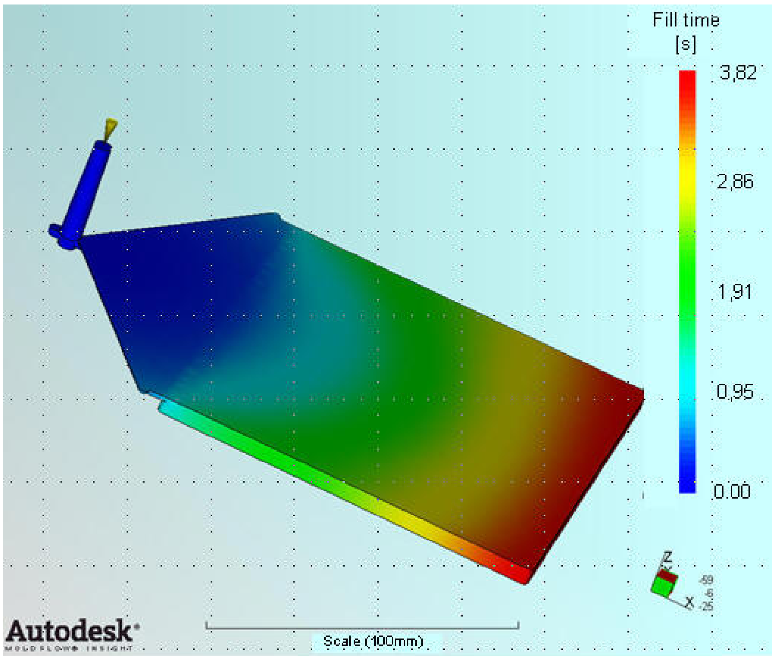
Generally, holding pressures should be high enough so that no sink marks or voids are left in the molded item. Adequate pressure transfer from the injection cylinder to the mold cavity is ensured by a melt cushion of about 3 to 5 mm (depending on the diameter of the screw). The sprue system must be large enough so that the holding pressure time on the molded part is long enough.

The optimum holding pressure time can be found by determining a seal point. If the holding pressure times are too short, this can cause sink marks and voids because insufficient material is fed from the space in front of the screw.

Cooling time

Table 10 contains some rough guiding values for the required cooling time in relation to the wall thickness and the temperature of the tool surface based on a simulation calculation. The calculation was made for a square plaque with 130 mm long sides (Fig. 9), different wall thicknesses, and a homogeneous (isotherm) surface temperature using Autodesk Moldflow calculations. Uneven tool surface temperatures prolong the necessary cooling times; if the tool temperature is 10°C higher, this prolongs the cooling time by about 20%. With complex component geometries the cooling time should be calculated in relation to the maximum wall thickness.

Fig. 9: Plaque 130 x 130mm²



Tab.10: Calculated cooling times at 200°C part temperature (demolding temperature) and different wall thicknesses using the example of a 130 x 130 mm² sheet

Wall thickness [mm]	Cooling time for VESTAMID® HT*plus* : Total of holding pressure and residual cooling time [s]					
	M1000		M1033		M1035	
	WT 140°C	WT 160°C	WT 140°C	WT 160°C	WT 140°C	WT 160°C
1	4	5	3	4	3	4
2	11	12	8	10	7	8

3	21	25	15	20	13	16
4	34	42	26	32	22	26

WT = Tool temperature

Production interruptions

If production is interrupted for up to ten minutes, we recommend that the melt be injected several times to the open air before production is resumed.

With longer interruptions, that is, over 15 minutes, we recommend that the system be purged with a highly viscous PP, a glass fiber reinforced PA66, or a suitable purging granulate (see "Cleaning").

The optimum setting for the respective process should be determined on the basis of the above information.

Handling and safety:

Since VESTAMID® HT*plus* is delivered with a moisture content less than 0.1%, we recommend drying before processing; usually a dehumidified air drying oven is used for this purpose. Open bags absorb moisture after just a few hours and the material should be dried again before it is used.

During processing, especially when rinsing, changing material and cleaning the injection cylinder, you should follow the usual safety precautions (switch on extraction, submerge melt cake in a water bath) and wear the usual protective clothing. Since tool temperatures can be as high as 180°C, precautions to prevent burning should be taken before these are handled.

Do not disable protection equipment on the injection molding machine (injection protection, sliding doors). Doing a job the wrong way, especially during rinsing and cleaning of the injection unit, can lead to injuries if skin comes into contact with the material.

Sources of the figures

- Ampco Metal, 82538 Geretsried, Germany
- BAWEMA, 90530 Wendelstein, Germany
- DME, 58511 Lüdenscheid, Germany
- GÜNTHER Heisskanaltechnik GmbH, 35066 Frankenberg, Germany
- GWK Gesellschaft Wärme Kältetechnik mbH, 58566 Kierspe, Germany
- Hasco Hasenclever GmbH & Co. KG, 58513 Lüdenscheid, Germany
- Meusburger GmbH & Co. KG, 6960 Walfurt, Austria
- Motan-colortronic GmbH, 88316 Isny, Germany
- STRACK NORMA GmbH & Co. KG, 58511 Lüdenscheid, Germany
- Synventive Molding Solutions, 64625 Bensheim, Germany
- Uddeholm, 40549 Düsseldorf, Germany
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