# Injection Molding Guide for KEPITAL

R&D Center

KOREA ENGINEERING PLASTICS CO.,LTD.

# 1. Safety recommendations

## (1) Safety precautions during processing

In processing KEPITAL, an extraction hood should be equipped over the barrel unit and measures should be implemented to ensure the ventilation of work place.
KEPITAL decomposes when subjected to excessive heating over 230 °C or residence time in cylinder at 200 °C or higher. The decomposition of KEPITAL generates formaldehyde gas which has a pungent smell and irritates the mucous membrane. Therefore, when thermal degradation is noticeable, the cylinder should be flushed by purging out melt and the cylinder temperature must be reduced at the same time. In order to prevent odor nuisance, thermally damaged material can be cooled down in a water bath. In addition, if material stays in a cylinder under the condition of a blocked nozzle, formaldehyde gas can rapidly build up a high gaseous pressure in the cylinder. When the pressure is elevated to a certain extent, the resin and gas in a cylinder are explosively discharged through the filling hopper, which could cause serious injury to operators and damage to the injection molding machine. It is therefore important to ensure the nozzle is never frozen or obstructed during processing.
KEPTAL is immiscible with almost all other plastics. If other materials are introduced and mixed, caution is required because problems including contamination, lamination, and deterioration of physical properties arise.
In case of a master batch that requires implementation of colors, a product based on KEPITAL is recommended. In particular, because if even a small amount of PVC resin is introduced and mixed, it causes serious degradation to the KEPITAL resin, it is good practice to prevent introduction and mixing of materials and also to use individual injection molding machines for PVC and KEPITAL only.

## (2) Changing material in processing

In general, the cylinder has to be cleaned with a polyolefin before and after KEPTAL processing.

## (3) The interruption of molding cycle

Molding cycles can be stopped and interrupted by technical malfunctions in the operating machine or other reasons. In this case, some treatments should be performed to prevent unnecessary problems. The barrel temperature should be lowered to 150 °C but the nozzle temperature may be maintained to prevent material from over-heating. If long-period interruption is expected, stop feeding granule and entirely eject the material out from the cylinder and then lower cylinder and nozzle temperatures. Conversely, increase nozzle temperature to 200 °C and then go up with cylinder temperature gradually when restarting machine with KEPITAL to prevent the nozzle from being blocked by frozen material.

## (4) Recycling of KEPITAL

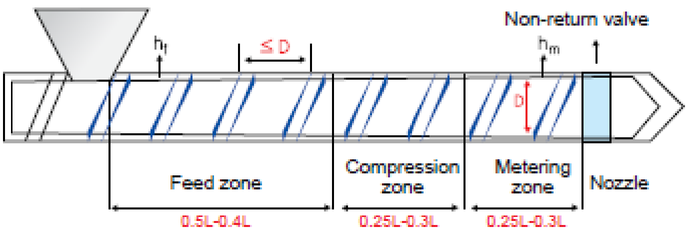
While recycled material mixing with virgin material does not particularly interfere with color difference, mechanical properties, and mold-ability, the high dosing rate of recycle is likely to cause contamination, and increase in the melt index is accompanied by recycled frequencies.

## 2. Injection molding machine

Injection molding is one of the common manufacturing methods for thermoplastics including KEPITAL as to allow even complicated design and cost-effective production.

Therefore, understanding the process of injection molding for KEPITAL is very important.
In order to obtain a high quality of product out of KEPITAL, the recommendations and check-points on the injection molding machine are as follows:

1) Open nozzle is recommended with individual band heater on the cylinder. This type of nozzle has advantages over other nozzles when it comes to dealing with gaseous products that result from thermal decomposition without pressure building-up when the molding cycle is stopped or interrupted with melt left in the cylinder for over-residence time to KEPITAL.
2) The non-return valve must be regularly checked to achieve holding pressure and cushion so as not to cause processed parts to have sink marks, or wide variations of weight or dimensions.
3) Compression zone in screw is recommended at 25 to 30 % of screw length. Improper compression zone length may not only over-heat material but also cause a lack of pressure build-up in the plasticizing.




[Recommendations on injection molding machine]
1) The one shot weight for KEPITAL is 20-50 % of machine capacity
2) L/D: 20~23
3) Compression ratio: 2:1~3:1
4) When processing glass-fiber reinforced KEPITAL, wear-resistant plasticizing unit is advisable and check wear on screw, regularly.

## 3. Injection molding condition

In mold fabrication, it is essential to previously review the dimensional precision, flow characteristics of the raw material, consistency of product, cost-effectiveness, etc.

### (1) Pre-drying

Being non-hydroscopic material, KEPITAL in its original packaging can be processed without pre-drying unless it is exposed to a humid atmosphere for a prolonged period of time. However, sometimes moisture that exists on the surface of pellets caused by improper handling or storage may result in a silver streak or nozzle drooling, so drying prior to molding may be necessary to prevent KEPITAL from these problems. In addition, in some cases, pre-drying is effective in reducing odor, mold deposits and in achieving a good appearance. Drying conditions are recommended at 80-90 °C for 3-4 hours.

### (2) Melt temperature

The melt temperature of KEPITAL in general is from 180 to 210 °C, preferably 190~200°C. Commonly, the melt temperature rises above the temperature at metering zone by 10-20°C, this results from mechanical shear heating during plasticizing.

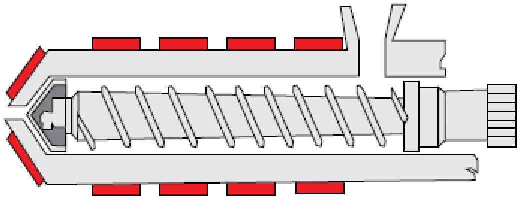


**Table 1. Typical cylinder temperature for KEPITAL**

| Grade | Nozzle | Metering zone | Com-pression zone | Feed zone |
|---|---|---|---|---|
| Unfilled standard<br>UV-stabilized<br>impact modified | 180<br>-<br>210 °C | 190 °C | 180 °C | 170 °C |
| FG<br>MF<br>FB | | 200 °C | 190 °C | 170 °C |
| The cylinder temperatures above are based on standard conditions and may vary with the capacity of the injection machine. | | | | |

When the melt improperly has a long residence time in the plasticizing unit, over-heating causes thermal degradation, which results in discoloration, impaired mechanical properties, etc. The processing window: temperature versus melt residence time in the cylinder for standard unfilled grade is shown in Figure 2.

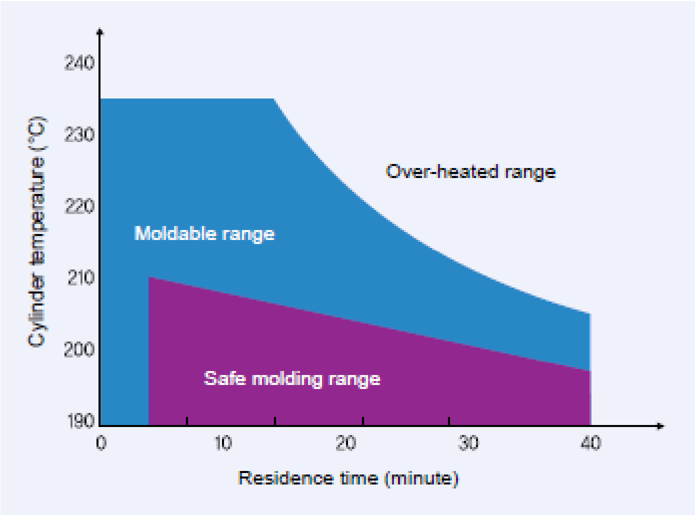



**Figure 2. Molding temperature versus melt residence time in cylinder**

## (3) Injection pressure

Injection pressure should be set high enough to achieve a high injection speed that may not be lowered by a low injection pressure. Appropriate injection pressure generally ranges 600 to 1200 bar.

## (4) Mold temperature

The mold temperature is one of the most important parameters for injection molding of crystalline polymer in particular. Mold temperature may widely be set up at 60-120 °C, and a general recommendation is 70-90 °C for general purpose of KEPITAL molding grades. If surface finish is important or the service temperature of finished parts are expected to be high, a higher mold temperature is recommended.
To obtain a good quality product, the mold temperature must be consistently maintained so that the temperature distribution in the mold may be achieved uniformly.

## (5) Injection speed

The injection speed should be determined by part geometry, gate size and location, surface features, flow characteristics, mold temperature, etc. In general, injection speed is set at high where there are flow marks, record marks, and sink marks; on the other hand, a low injection rate is good to prevent jetting, blushes, burn marks, or gate smear generated by high shear force against cavity wall.

## (6) Hold pressure

Hold pressure plays a key role in making KEPITAL parts optimized not only in dimension but also in mechanical & physical properties. Because in the hold stage (hold/pack), remaining melt for about 1~5 % of a cavity is forced to fill into the cavity to compensate for the volume contraction during cooling. The hold (pack) time must be set to slightly exceed the gate seal time (normally ½ to 1 sec) at which a gate is completely solidified so a consistent product may be obtained. As shown in Figure 3, the weight of a molded part increases upon the hold pressure time and then stops at a certain point. At this time the gate of the part is solidified entirely and no more material can be incorporated. Finally part weight shows consistent after

the gate seal time.
It is recommended that the hold pressure time be maintained until the gate seal is completed. Because the gate seal time changes mostly upon the shape of cross-section and mold temperature, a proper hold pressure time must be determined such that the weight and dimension of a molded product are within a certain range.
By setting optimum hold pressure, molded parts products with consistent dimensions can be produced. As a rule of thumb, the hold time can be simply calculated by wall thickness (mm) times 8.
The hold pressure must be set in consideration of dimensional requirements. As a rule, hold pressure amounts to between 60-90 % of the injection pressure.

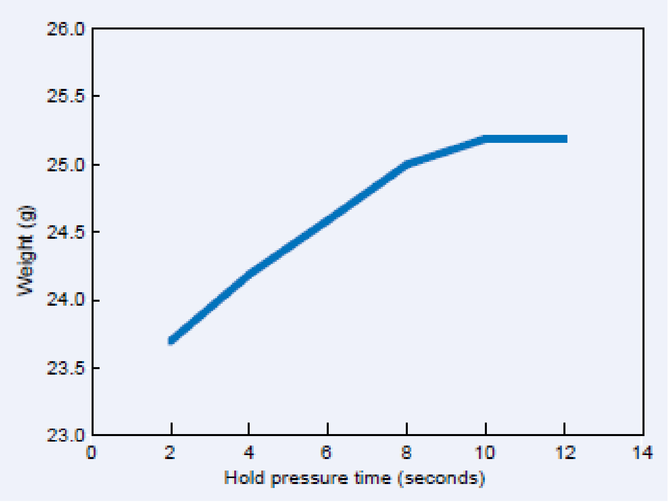



**Figure 3. Hold pressure time and product weight**

## (7) Plasticizing

Because plasticizing by an excessively fast rotating speed can make KEPITAL decompose by high shear force, the reciprocating speed is preferably set as low as possible unless it does not affect cycle time. Since screw RPM is dependent on screw diameter, screw line speed by screw can be utilized. As a result, screw line speed is recommended in the range of 150 mm/s to 200 mm/s, and with respect to the diameter of screws following can be chosen.

**Table 2 Screw rotation speed versus screw diameters**

| Screw diameter | 25 mm | 40 mm | 55 mm |
|---|---|---|---|
| Screw rotational speed (rpm) | 120 | 100 | 70 |

A back pressure of 10-20 bar is generally appropriate. However, to increase the efficiency of the dispersion of a color master batch (color concentrates) or pigment, higher mixing by increasing back pressure may be required.
In addition, high back pressure may be used to eliminate un-melted particles. In the case of glass fiber reinforced grades, high back pressure, proportional to rotational speed leads to breakage of the glass fiber, resulting in deterioration of mechanical strength. More importantly, excessive back pressure gives rise to lower output along with longer cycle time. Therefore it should be taken into consideration when optimizing the back pressure.

## (8) Cooling

Total cooling time is determined as the sum of “hold pressure time + screw retraction time + a shot safety margin”. Once KEPITAL is solidified entirely, no additional cooling time is needed. Most of the time affecting the cooling time is the hold time. Therefore, supposing a hold pressure time is set appropriately, only screw retraction time needs to be taken into account.

In case of a high crystalline resin like KEPITAL, sometimes prolonged cooling time at a high mold temperature may be applied to minimize the residual stress.

| Calculation of theoretical cooling time |

$$S = \frac{t^2}{\pi^2 \alpha} \ln \left[ \frac{8}{\pi^2} \frac{(T_c - T_m)}{(T_x - T_m)} \right] \qquad \alpha = \frac{R}{C_p \rho}$$

- $S$ = Theoretical cooling time
- $t$ = Maximum part wall-thickness
- $\alpha$ = Thermal diffusivity of material
- $R$ = Thermal conductivity
- $Cp$ = Specific heat
- $T_x$ = Ejection temperature of molding
- $T_m$ = Mold temperature
- $T_c$ = Cylinder temperature

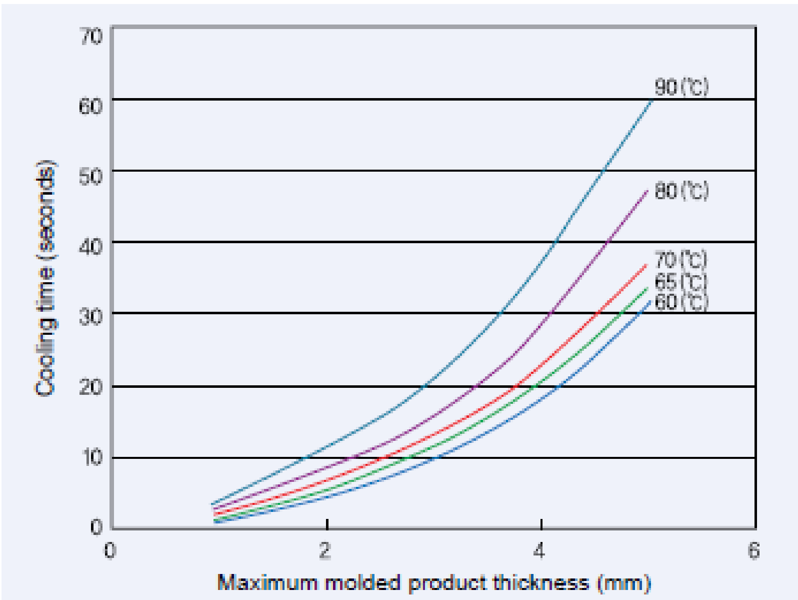



**Figure 4. Cooling time versus mold temperature**

## (9) Flow characteristics

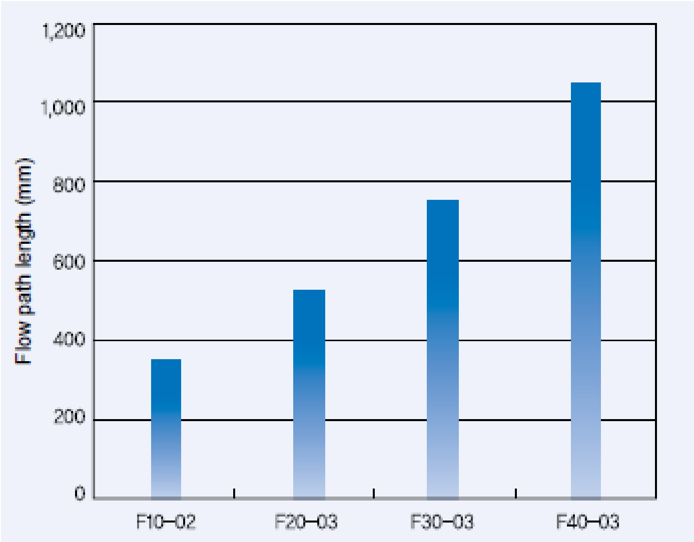



**Figure 5. Flow path length of unfilled standard grades (melt temperature 200 °C, injection pressure 600 bar, thickness 3 mm spiral flow test)**

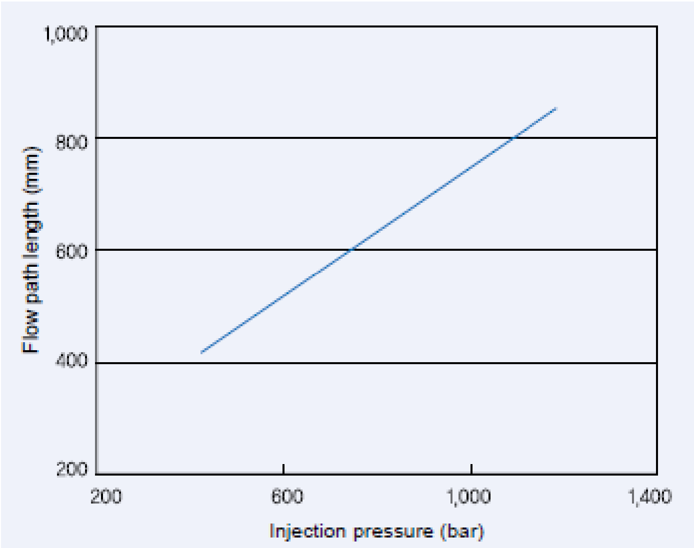



**Figure 6. Flow path length of KEPITAL F20-03 as a function of injection pressures (melt temperature 200 °C, thickness 3 mm spiral flow test)**

Figure 5 shows the results of the spiral flow test in which the flow properties of standard unfilled grades were evaluated. Influence on flow-ability is found to depend greatly on molecular weight. In addition, Figure 6 shows the spiral flow test results of F20-03 at different injection pressures, indicating that flow characteristics tend to increase with higher injection pressures.

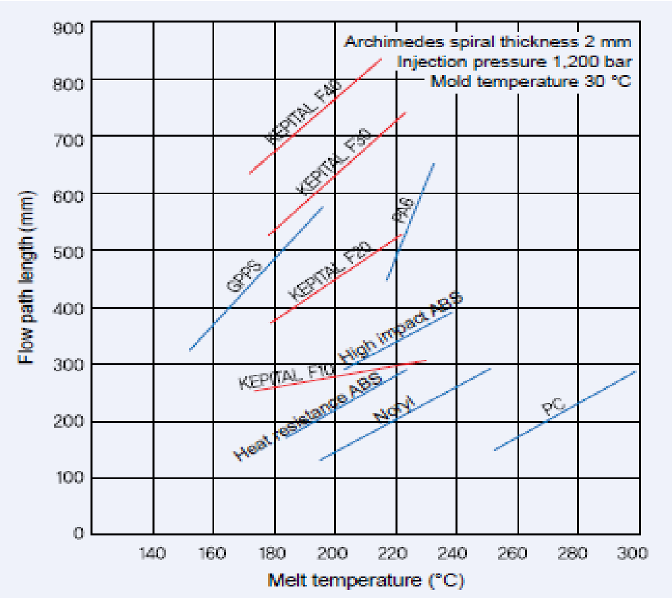



**Figure 7. Flow characteristics of KEPITAL and other plastics during injection molding**

## (10) Cycle time

Cycle time varies with injection time, hold pressure time, cooling time, mold open time and safety margin at each cycle. More importantly, cycle time is closely related to part thickness. From a molder's stand point, shorter cycle time is preferable; however, optimizing all time-dependent parameters such as fill rate, hold pressure time, and cooling time is very important to get quality parts out of KEPITAL.

## (11) Shrinkage

The shrinkage rate is the most important factor in determining a product's dimensions and is obtained from the sum of mold shrinkage and post-mold shrinkage. The shrinkage value, provided by KEP, can be utilized in designing a part in the prototype phase. However most of the shrinkage behavior is affected by not only the plastics' characteristics but also the processing conditions and part geometry. Therefore, the shrinkage rate must be taken into account in consideration of all possible factors.
When mold temperature increases, the mold shrinkage rate increases, and post-mold shrinkage rate decreases.

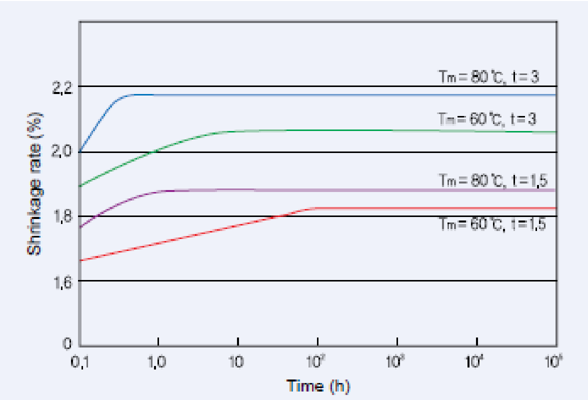



**Figure 8. Shrinkage rate changes with mold temperature and specimen's thickness**

In general, when the injection pressure increases, the shrinkage rate decreases. Dimensions of a product can be adjusted by changing injection pressure and hold pressure & time.

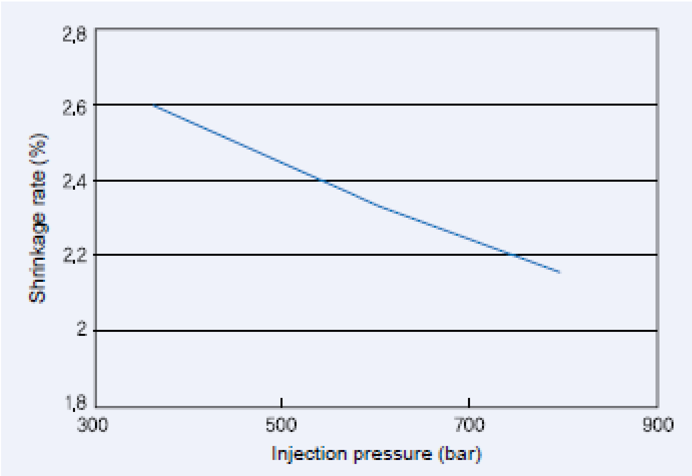



**Figure 9. Shrinkage rate changes with injection pressures**
**(F20-03, melt temperature 200 °C, Specimen diameter 100 mm, thickness 2 mm)**

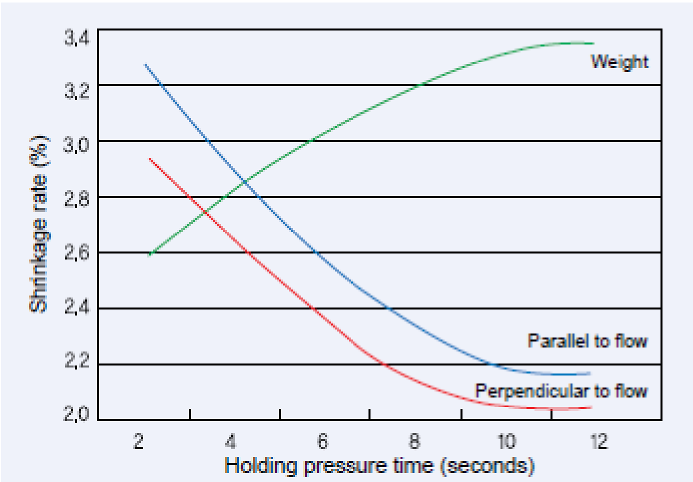



**Figure 10. Shrinkage rate changes with holding pressures**
**(F20-03, melt temperature 200 °C, Specimen diameter 100 mm, thickness 2 mm)**

Figure 10 demonstrates that shrinkage rate is high if hold pressure time is shorter than gate seal time.

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