TELENE PART AND MOULD DESIGN GUIDE

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1. **Design Criteria**

1.1 **Polymer Properties**

Telene 1650 is the most commonly used grade of Telene. Telene 1650 mechanical properties according to the data sheet [2]:

- Polymer specific gravity: 1.03 gr/cm³  ISO 1183
- Tensile modulus: 1870 MPa  ISO 527
- Tensile strength @ yield: 43 MPa  ISO 527
- Elongation @ yield: 5%  ISO 527
- Flexural modulus: 1850 MPa  ISO 178
- Flexural strength: 67 MPa  ISO 178
- Impact strength:
  - Notched Izod @23°C: 30 kJ/m²  ISO 180/A
  - Notched Izod @- 30°C: 16 kJ/m²  ISO 180/A
- Rockwell hardness: HHR 114  ISO 2039-2
- Glass transition temperature: 155°C  Telene Method 1
- Heat distortion temperature (HDT) under 1.8 MPa: 120°C  ISO 75/A Tfe1.8
- Linear thermal expansion: 79x10⁻⁶ m/m/°C  ISO 11359

**Properties at Low Temperature**

Mechanical properties at -60°C:

- Tensile modulus: 2451 MPa
- Tensile strength @ yield: 78 MPa
- Elongation @ yield: 5%
- Flexural modulus: 2446 MPa
- Flexural strength: 129 MPa

**Properties at High Temperature**

Refer to graphs on Figure 1 for tensile modulus and yield strength at various temperatures.

**Fire Behaviour**

Being an hydrocarbon polymer solid oil, Telene is prone to burning with heavy smoke emission of nontoxic fumes. Oxygen index is 19% per ISO 4589. Telene burning behaviour strongly depends on attitude (horizontal or vertical) of the specimen during the test, and it has been evaluated per various industry and customer standards, refer to specifications [6, 7] for details. Specifically, a 3mm thick specimen passed requirements of Directive 95/28WE relating to the burning behaviour of materials used in the interior constructions of certain categories of motor vehicle**, Annex IV: To determine the horizontal burning rate of materials**.
Aging
Aging of Telene originates in oxidation. When oxygen diffuses in the polymer, it reacts with the remaining double bonds to create oxidized groups, especially when activated by heat and UV. The phenomenon is limited by the oxygen diffusion in the polymer. Below the glass transition temperature, the degree of diffusion reaches a plateau and stabilizes. A layer of paint limits the rate of oxidation and protects the polymer from the UV.

Aging results in changes of the properties such as decreased:

- elongation at break: 4% (from initial 25-30%)
- impact resistance: 20 kJ/m² that is 65% of the initial value,

and increased:

- tensile and flexural Modulus + 10 %
- tensile and flexural Stress at Yield + 10 %
- HDT: +10 °C

Refer to [5] for more information.

![Figure 1](image_url)
Creep behaviour

Creep is the tendency of a solid material to move slowly or deform permanently under the influence of mechanical stresses. It can occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material. Unlike brittle fracture, creep deformation does not occur suddenly upon the application of stress. Instead, strain accumulates as a result of long-term stress. Therefore, creep is a "time-dependent" deformation.

Creep, as a material property, is normally expressed as percentage of elongation under constant stress level as a time function. It depends on temperature and initial level of stress. Some graphs outlining creep behaviour of Telene are shown at Figure 2 and Figure 3.

**TELENE 1650 Tensile creep @ RT**

![Graph showing tensile creep behavior at room temperature](image)

**TELENE 1650 Tensile creep @ 60°C**

![Graph showing tensile creep behavior at 60°C](image)
Fatigue behaviour
Fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less, than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit. An S-N curve has been developed for Telene (Figure 4). For details, refer to [10].

Chemical Properties
Telene chemical resistance depends on the type of exposure, concentration of chemicals, exposure time and temperature.
The three groups of chemicals that Telene is resistant to are as follows:
- Organic solvents: no long time exposure shall be considered due to swelling.
- Mineral solutions: excellent resistance during long-term exposure at high concentration and high temperature.
- Oxidizing compounds: resistance is limited in temperature and concentration

For a complete table with Telene corrosion resistance properties contact Telene SAS.

Electrical Properties
- Resistivity at 23°C – 2.5x1015 Ohm x cm ASTM D257
- Dielectric constant at 23°C – 2.78 (@60Hz), 2.76 (@1Mhz) ASTM D150
- Dissipation factor at 23°C – \(0.86e^{-3}\) (@60Hz), \(2.1e^{-3}\) (@1Mhz) ASTM D150
- Arc properties – 84sec ASTM D495
- Breakdown voltage – 19-20kV/mm ASTM D149

For the complete datasheet, refer to [9].
Heat Capacity of Telene Polymer of Non-Reinforced Grades
For heat capacity, refer to Figure 5.

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<tr>
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<th>Cp J/gK</th>
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<td>220</td>
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<td>2.362536</td>
</tr>
</tbody>
</table>

*Figure 5*
1.2 Design Criteria

Prior to designing, application requirements should be collected to evaluate all constrains applicable to the part throughout its life cycle, i.e. applied not only during service life, but also during transportation, storage, installation and at the end of part's life. Special attention must be paid to cases when Telene replaces other materials, e.g. steel, when, as practice shows, requirements can be easily missed. Part's specifications may include, but is not limited to:

- a definition whether the part belongs to the primary or secondary (“cosmetic”) structures;
- a description of the way the part joints or interferes with other surrounding components or structures;
- loads acting upon the part;
- other operating conditions like, for instance, temperature and environment exposure.

1.3 Finite Element Analysis (FEA)

Finite element analysis is an engineering calculation method that allows a design engineer to simulate Behaviour of the part under well-defined loading conditions. The quality of simulation is highly dependent on the quality of finite element mesh, adequacy of constraints and loads applied to the model of the part, as well as on the input data needed to perform the analysis. Numerical results of an FEA analysis are post-processed to visualize, for instance, stress distribution, and displacements at each point of the part, thus allowing the design engineer to check the deformed mode of the part versus material properties and/or boundary and loading conditions. In most of the cases, Telene part deformation is large enough to require a non-linear analysis.

- Glossary:
  - Model: a mesh model is created from the CAD model. Different types of finite elements can be chosen: 2D (with 3, 4 or more nodes) or 3D (4, 6, 8 or more nodes). Usually, especially at early design stages, small geometrical features, such as fillets, can be omitted while generating a FE-model of the part. They can be implemented at later stages as appropriate.
  - Material properties: materials are modelled by some values as Young modulus, Poisson ratio, and more (for plasticity, creep, etc...). They can depend on temperature.
  - Boundary conditions: constraints need to be defined at each location where the part contacts its supporting structures and/or surrounding components. In other words, one has to take away appropriate degrees of freedom from appropriate points of the model. Contact conditions are available.
  - Operating conditions: Usually limited to temperature conditions.
  - Load cases: combinations of the loads, boundary conditions and operating conditions applied to the model.
  - Types of loads: they can be, for instance, static or dynamic (vibration, rotating forces, etc...), local or distributed forces (per unit length, unit surface, pressure, volumic load like acceleration, temperature map and others). They need to be defined accordingly.
The purpose of the following is to categorize the various FE-analysis commonly done on Telene parts. All this type of FEA can be provided by FEA service consultants or through Telene Technical Service. Specific documents describing input parameters needed for running FEA are available on Telene web site in the Technical Bulletin section.

**Static and Quasi-Static Analysis**

This type of FE-analysis is the most common one. The load is either static or varies very slowly in time. Multiple load types can be easily combined to cover complex situation. Typically, acquired results are stress distribution and deformation, that can then be compared to either Telene material properties or part design constrains like acceptable deflection, safety margin under certain load conditions.
As with all polymers, Telene is prone to creep; this is taken into account through the design allowable:
- Creep situation: 10% of the yield stress
- Temporary or intermittent load: less than 4% elongation

An Example of a Static Case

Modal Analysis
Modal analysis is a key type of analysis for body panels. The results of such analysis are eigen mode shapes and frequencies of the part during free vibration for certain boundary conditions. Modal analysis is an easier and faster FEA to perform than any other types of FEA, and it is often a good start to design/analyse the part.

Often, only the lowest frequency mode is considered that then can be compared to the part design specification, e.g. “No eigen frequency below 15 Hz”. Deformed and undeformed shapes are shown overlaid below.
Dynamic Response Analysis

Excitation is imposed on the structure fixations. This excitation can be a combination of excitations on different directions, if the phases are known. Damping is taken into account by a damping factor, typically 3%.

Two calculations can be made:
- a complete one, which gives stresses and strains everywhere on the part, at any moment.
- a quicker one, based on modal combinations, which gives only the highest values of stresses and strains everywhere on the part, for all moments.

Impact Simulations

Both a part and either an impactor or an impacted object are modelled and put in contact. The relevant inertial loads are then applied using the initial speed. Time step size is adjusted such that stresses and strains variations are not too large between two steps to allow the calculation to converge. Plasticity can be taken into account. Friction, too, can be taken into account, if the friction coefficient is known. In practice, impact simulations done on Telene parts are mainly run to simulate qualification tests where an impactor generally arrives perpendicular to the part surface. In that case neglecting friction is an accepted practice. In the case of impact involving high mass and/or high speed, optimized crash FEA solvers should be used.
Thermal Analysis
Thermo-mechanical and thermal analysis
It is possible to simulate deformations due to temperature along to mechanically induced deformation. The temperature distribution can be heterogeneous throughout the part and given as a temperature map resulting from an experience or calculated as a result of conductive, convective or radiative processes.

1.4 Thermal Deformation

Thermal expansion is an intrinsic property of all materials. Typically, for non-reinforced grades of Telene coefficient of linear thermal expansion (CLTE) is about 80-6 m/m°C, and much less for reinforced grades. As an example, for a 1m long part, which is a typical dimension for a vehicle body panel, it results in a 8mm elongation/contraction within a 100°C temperature range, e.g. -40…+60°C. Therefore, fastening such a part to the structure needs to have some play.

Deformation due to thermal expansion can be handled. One of the most efficient methods is to design the part, in purpose, slightly curved, so that the thermal deformation is absorbed by a change of radius.

In the case of flat parts, S-like distortion may happen and make the deformation highly noticeable. If a flat part design is not avoidable, it is recommended to fix the part at its centre, and arrange movable supports on its sides (slots, flexible fixations, and so on).

A CLTE calculation sheet is available on request to Telene Technical service.
2. Part Design

2.1 Part design

Parts manufactured from Telene have no theoretical size limit. While Telene 1650 has been designed for parts weighing up to 25-30kg, assuming a 100kg/min RIM-equipment, special grades of lower reactivity can be supplied. In combination with a more powerful RIM-unit, this significantly widens the range of part sizes. Parts weighing a few hundred kilos are routinely produced.

Visible Surface Considerations
The designer should understand some specifics of the DCPD RIM-process affecting quality of the part surfaces. It should be kept in mind that the higher quality surface is obtained on the hotter part of the mould. For parts similar to body panels, one usually considers an outer visible surface (A-surface) and an inner/back surface (B-surface) of the part, with higher surface quality requirements to the outer side. As a rule, this is the cavity side of the mould. The surface formed by the core of the tool would be of lower quality.

Thickness
Minimum recommended thickness for Telene part is 3mm. The value is based on the temperature peak during polymerization and aging of Telene. Polymerization of Telene releases heat that allows the polymer to fully convert and to reach its ultimate properties. Thickness below 3mm results in a significant percentage of heat being lost into the mould therefore reducing conversion and affecting physical properties. Also, reducing Telene thickness increases the relative percentage of polymer that is affected by surface oxidation.

Wall thickness variation for the same part can be rather wide, but should be designed with care to avoid visible shrink marks (see Polymerization Shrinkage).

Polymerization Shrinkage
Polymerization shrinkage is a physical phenomenon determined by arrangement of molecular chains. Linear shrinkage depends on the relative speed of polymerization in the various directions mainly determined by the mass of reacting material and the temperature profile of the tool. Shrinkage should be taken into account early in the part design stage to prevent:
- shrink marks on A-side of the part due to abrupt thickness changes or similar geometric features of the part;
- distortion due to overall part geometry, and inappropriate thickness distribution.

Approximately 1% linear mould shrinkage can be expected both parallel and perpendicular to the flow direction. The bulk of the volume change goes through the thickness, i.e. perpendicular to the surface direction.

In addition to the polymerization shrinkage, thermal shrinkage linked to the operating temperature of the tool should be taken into account. Refer to the “Mould Design” section for practical shrinkage values.

A rapid increase or decrease in part thickness may cause a local shrinkage effect. This would be visible and might adversely affect the aesthetics of the part. Some examples of such rapid changes of thickness are reinforcement ribs on the back of a panel, bosses for inserts and sharp angles instead of gradual increase/reduction of thickness of a curved part.

To minimize the effect of shrink marks the designer should follow principles illustrated in Figure 12:
- ensure smooth transition between areas with different thicknesses;
- hide the shrink mark by locating the thickness change line behind/under geometry features of the part;
- consider the addition of intentionally designed geometry to cover anticipated shrink marks.

**Ribs**

Ribs (Figure 13) are often used to stiffen the part without significantly compromising its weight when compared to skin thickening. The drawbacks inherent to ribs are shrink marks, difficulties in mould filling and part demoulding.

Rib to skin thickness ratio of 0.6 applied to the design significantly reduces the shrink mark, although this cannot guarantee elimination of the problem. For non-aesthetic parts, the rib can be as thick as the skin of the panel, and even thicker. The usual practice of hiding of shrink marks behind/under part’s natural (or special) design features, e.g. steps, as described above, is recommended whenever possible. Other steps to minimize the effect are to orient the ribs along the filling flow, and ensure that the ribs do not stick to the core. The latter is specifically true in the case of multiple ribs present on the core side and usually implies use of increased draft and even ejectors for demoulding.

To avoid rib filling issues, whenever possible,
- try to orient ribs parallel to the anticipated direction of flow;
- use slopes/chamfers at both ends of the rib or connect the rib to the part wall;
- oversized reservoirs/false vent can be considered for venting.
Bosses

Bosses are typically used to provide fixation points. The previous suggestions on designing ribs apply to bosses as well. To improve venting, top venting rings gussets and can be used as shown on Figure 14 and Figure 15 respectively.
As an alternative to moulding a single-piece part with ribs and/or bosses, if shrink marks are absolutely unacceptable, one can consider bonding a reinforcing element to the B surface of the main part. An example of an “omega-shape profile” is shown at Figure 16.

![Figure 16](image)

**Fillets and Radii**
Generous fillets and corner radii are recommended. Sharp corners should be avoided as they can trap bubbles and create stress concentrations. Therefore, it is recommended to apply at least a 1.5mm radius fillet to exterior and interior corners of a part design. 2 to 3mm radius fillets are specifically recommended for corners opposing the parting line (Figure 17).

![Figure 17](image)

**Edge Design for Deflashing**
Additionally to the problem with bubbles described in the previous paragraph, deflashing of sharp edges may result in their roughness as illustrated at Figure 18.

![Figure 18](image)
To prevent rough edges, it is recommended to maintain regular thickness of the part as shown at Figure 19.

Figure 19
Draft
Draft primarily serves to facilitate part demoulding and to prevent part surface damage/marring by the mould. In usual process conditions (mould run with hotter cavity side than core side), the temperature differential tends to maintain the part on the cavity side. A minimum draft angle of 3° is recommended on the cavity side of the mould (Figure 21), and 1.5° on the core side (Figure 20).

Due to shrinkage of the part, outer walls of the part may have no draft on the cavity side.

In the case of deep pockets or recesses located on the cavity side, shrinkage will have tendency to lock the part on the cavity. Therefore, one has to consider increasing the draft angle on cavity to 7° or more in order to facilitate the demoulding. Alternatively, ejectors can be implemented to facilitate demoulding.

Several typical shrinkage cases, assuming a cold core and hot cavity, are as follows.

1. Shrinkage helps demoulding. A 0° draft is acceptable (Figure 22)
2. Shrinkage works against demoulding (Figure 23). A 3° draft is acceptable, if the recess is -
   a. less than 30mm deep, or
   b. open on two sides, or
   c. large enough to be flexible.

![Figure 23](image)

3. Comments on case #2 are also valid for case #3 (Figure 24). Shrinkage in this example is worse when the distance between the two recesses is increased.

![Figure 24](image)

**Undercuts**
Undercuts naturally cause a problem during the demoulding stage. The standard solution assumes movable blocks within the mould. Refer to section “Mould Design”.

**Moulded Openings**
Moulded openings can be incorporated into the design of a Telene part. Appropriate venting of the part in the area of the opening feature must be considered, refer to section “Mould Design” for details.

**Mechanical Fastening of a Telene Part**
The most common way of assembling/mounting a Telene part is via mechanical fasteners. Inserts and self-tapping screws are covered in this section of the guide. Holes and slots used to assemble a Telene part may require anti-creep washers or spacers. Other types of fastening, for example clips and cage nuts (see Figure 25), are outside the scope of this guide, as they usually do not require any special design.
A part can be designed with integral fasteners. Depending on aesthetic requirements, and potential moulding constraints (usually undercuts or die lock), fasteners may also be located on omega reinforcements or smaller individual blocks that are bonded in place during finishing operations. The most commonly used type of mechanical fasteners are overmoulded or post-fixed inserts providing reusable threaded connections, as well as screws described below.

Overmoulded Inserts
As a rule, encapsulated inserts are used when high torque resistance is required. They are positioned in the open mould, and are then mechanically locked in place during the polymer curing stage. A minimum thickness of 5 mm of Telene should be provided around the insert to avoid high stress in the polymer. Inserts are usually made of steel, and can be plated for corrosion protection purposes. Inserts that have shown good functionality include those with peripheral knurling or other interlocking means, as well as some kind of direct pull-out protection such as a shoulder, step, enlarged head-like area, etc. Typical designs are shown on Figure 27 and Figure 28.

Use of inserts in a mould requires proper mould design and process procedures to avoid mould damage. There are several ways to secure inserts into the tool. As the inserts are most often located on the upper half of the mould (in process position), a combination of metal pin and magnet is widely used. Plastic insert holders are also very common (see Figure 26). When the insert axis cannot be orientated in the demoulding direction, use of intermediate mould components or movable pins are required.

Overmoulded inserts should be carefully located to minimize shrink marks on the cosmetic surface of the part. Directly opposite from design lines and features, or part edges are preferred locations for encapsulated inserts. For class A surface applications and designs, additional Telene pieces that include all the inserts are normally bonded on the B side of the class A skin to prevent any read-through on the cosmetic surface. Pull-out strength and torque resistance of several insert designs are summarized in
Table 1. These values have been obtained with 5 to 6 mm of Telene surrounding the insert.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>M5 B/R</td>
<td>11</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>M6 B/P</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>M8 B/R</td>
<td>17</td>
<td>4</td>
<td>5</td>
<td>14</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>M8 B/P</td>
<td>12.5</td>
<td>3</td>
<td>4</td>
<td>10</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>M10</td>
<td>25</td>
<td>7.5</td>
<td>10</td>
<td>22</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>M12</td>
<td>25</td>
<td>7.5</td>
<td>10</td>
<td>23</td>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

**Figure 27**

<table>
<thead>
<tr>
<th></th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>M5</td>
<td>4</td>
<td>&gt;10</td>
</tr>
<tr>
<td>M6</td>
<td>4.75</td>
<td>&gt;12</td>
</tr>
<tr>
<td>M8</td>
<td>6.5</td>
<td>&gt;15</td>
</tr>
<tr>
<td>M10</td>
<td>8.2</td>
<td>&gt;18</td>
</tr>
<tr>
<td>M12</td>
<td>9.9</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>

**Figure 28**
### Table 1

<table>
<thead>
<tr>
<th>Insert Type</th>
<th>Telene Thickness, mm</th>
<th>Pullout Strength, N</th>
<th>Torque Resistance, N-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>M5 B/R</td>
<td>5</td>
<td>2370</td>
<td>-</td>
</tr>
<tr>
<td>M6 B/P</td>
<td>6</td>
<td>3750</td>
<td>15</td>
</tr>
<tr>
<td>M8 B/R</td>
<td>5.5</td>
<td>4040</td>
<td>25</td>
</tr>
<tr>
<td>M8 B/P</td>
<td>5</td>
<td>4290</td>
<td>25</td>
</tr>
<tr>
<td>M10</td>
<td>5</td>
<td>14780</td>
<td>70</td>
</tr>
<tr>
<td>M12</td>
<td>5.5</td>
<td>19690</td>
<td>130</td>
</tr>
</tbody>
</table>

Post-Mould Installed Inserts

Unlike overmoulded inserts, this type of fastener is installed during finishing operations after the part is demoulded, thus decreasing the moulding cycle time, and eliminating potential tool damage due to poor insert handling. They are often used when medium pull-out and torque resistance are required. The inserts are either screwed or forced in place in a prepared location, with the choice between the two methods depending on the pull-out requirements.

Refer to supplier’s Technical literature for performance of inserts and recommended dimensions of installation bore.

Figure 29 and Figure 30 show some post-moulding fixed inserts examples (courtesy Tappex Thread Inserts Ltd and EJOT GmbH & Co. KG).
Self-Tapping Screws

Self-tapping screws specifically designed for plastics can be used with Telene RIM polymer. As a rule, the nature of the self-tapping makes this type fastening non-reusable.

To reduce read-through of the bosses, it is recommended to core-out the screw hole up to the level of the nominal part thickness. Caution should be used not to exceed allowed torque that can result in part deterioration.

Tests performed using EJOT Delta PT 40 - Ø4 x 12 mm screws at 8 mm length, demonstrated a pull out force of 2750 N and torque resistance of 2.7 N-m. Refer to Figure 31 for example of typical self-tapping screw boss design (courtesy EJOT).

![Diagram](image.png)

\[ d_1 : \text{Nominal screw diameter} \]
\[ d_b : \text{Boss diameter} = 2 \times d_1 \]
\[ d_h : \text{Passing hole} = d_1 + 0.3\text{mm} \]
\[ d_c : \text{Counter bore diameter} = d_1 + 0.2\text{mm} \]
\[ d_h : \text{Hole diameter} = 0.8 \times d_1 \]
\[ t_c : \text{Counter bore depth} = 0.3 \text{ to } 0.4 \times d_1 \]
\[ t_e : \text{Screwing length} = 2x d_1 \]
\[ \text{Chip space} = 0.8 \text{ to } 1.2 \times d_1 \]

*Draft angle not represented on the boss*
2.2 Tolerance on Moulded Part Dimensions

As a general rule, use +/-0.2% tolerance for linear dimensions. This results in better tolerance than prescribed by commonly accepted standards for plastic parts, e.g. DIN 16901. For quality assurance purposes, the dimensions should not be measured before 48H after moulding. Wrong selection of the mould shrinkage coefficient may adversely affect the dimensions, resulting in out-of-tolerance parts (refer to “Mould Design” section). For a part of variable thickness, selection of the mould shrinkage coefficient is always a compromise between different options. RIM process parameters may also affect the dimensions up to a certain degree.

2.3 Bonded Structures

Telene parts can be easily bonded with many adhesives. Both substrate to substrate bonds and metal to substrate bonds are routinely performed. Acrylic, epoxy, urethane, methacrylate and silyl modified polymer (MS polymer) based adhesives are commonly used. Due to relatively low modulus and yield/ultimate stress values, plastics generally require a generous bond line area to withstand loads. Bond lines should be designed to minimize peel type loads. This is usually accomplished by providing an extended area on one of the bonded members typically in the range of 20 to 25 mm. Bond line stand-offs can be moulded in to the respective members insuring proper bond line thickness without additional parts or spacers. Spacer height depends on the type of adhesive used, and is usually between 0.5 to 3 mm. It is recommended to avoid continuous stand-offs to allow adhesive excess outflow.

Metal to plastic bonding is best accomplished with a high elongation adhesive that can accommodate the differential in coefficients of thermal expansion. The larger/longer the bonded areas, the greater the possibility that some bond line failure may result from this difference. Thicker bonded joints will help accommodate thermal induced stress. This is especially critical for plastic to metal bonds made prior to painting (paint line thermal cycling). Bonded structures creating a closed volume should not be allowed as the thermal expansion of the enclosed air volume creates surface distortion or induces unnecessary stress in the bonded area.

Common Telene bonded structures typically include a relatively thin Telene skin, and one or more bonded “top-hat” (also called omega shape) reinforcements. If the reinforcement is located on a large flat surface some bond line area read-through may be seen. This visible line can be greatly reduced by appropriate bonding line design, adhesive selection, and accurate bonding fixtures. Protecting bond lines from peel forces is recommended for all bonded structures. A thorough knowledge of loads on the part, as well as the properties of the adhesive materials and substrates is necessary. It is recommended to perform a finite element analysis of bonded structures to insure proper bond line orientation, stresses, dimensions and locations. Prototyping of production parts is often used for validation.

Adhesives

Various substrates can be bonded to Telene. The most common are metals and other Telene parts. Surface preparation is extremely important in obtaining consistent results. Polyurethane and epoxy adhesives work well on Telene along with methacrylate systems. Silyl modified polymer based products offer a flexible isocyanate free system. Recent developments with methacrylate systems have resulted in materials giving very strong adhesion to Telene without the need to sand the bonded surface. This provides a significant cost reduction for finishing operations.
Selection of an adhesive depends on multiple properties that are linked to part requirements, design criteria (possible joint design) and acceptance by the part manufacturer. Criteria such as required strength, temperature resistance, thermal expansion in service, substrate to be bonded, surface preparation, handling, and curing time are key factors to consider when selecting an adhesive. Evaluation and testing should be performed with all substrates to determine bond strength, and should be carried out according to the adhesive manufacturer mixing and application instructions. Adhesive failure can be either adhesive or cohesive. Type of failure and failure level will guide adhesive selection. Refer to Telene Process Book for processing details [1].

### 2.4 Overmoulded Polymer Inserts

The only two polymer families that Telene has adhesion to are polyethylene and polypropylene, as well as some co-polymer derivatives. The level of adhesion depends mainly on the thermal properties of the chosen polymer in relation to the heat generated during polymerization. As an indication, a 5 mm Telene thickness has been found sufficient to give adhesion to most of the PE or PP based inserts. For more detailed recommendations it is recommended to contact Telene Technical Department.

### 2.5 TELENE Part Identification

According to ISO 11649 – “Plastics - Generic identification and marking of plastics products” – and ISO/DIS 1043-1.2 – “Plastics - Symbols Part 1 : Basis polymers and their special characteristics” - Telene parts shall be marked as follows:

```
> PDCPD <
```

Where applicable, refer to local standards for part identification.
3. Mould Design

3.1 Part Size / Clamping Force

The size of the part naturally drives the size of the mould, and therefore the size of the platens and daylight of the press holding the mould. The press should develop a clamping force greater than the one needed to keep the mould just closed during filling or polymerization, whichever develops higher pressure in the mould. This pressure depends a lot on the operating conditions and choice of formulation reactivity, allowing to use relatively low closing force per press platen surface unit for press design, typically in the range of 1.5 to 2 kg/cm$^2$.

3.2 Mould Design for Telene 1600 Series

When designing a Telene RIM mould, the following parameters that affect part quality and mould cost should be taken into account:

- Mould material selection
- Parting line / Gasket
- Gate location
- Venting
- Flash design

Other parameters that will affect the processing performance of the tool are as follows:

- Heating / cooling lines design
- Guide pins
- Handling devices

This section will cover most of these key points, including mould shrinkage. Refer to section “Mould Gate Design” for additional information on gate design and location.

Mould Material Selection

There are many factors to be considered when selecting tooling material, and among them are such criteria as the required part surface quality, production volume, part size, mould cost and ability to change or repair tools.

This section provides only generalized rules. Tooling material selection and tool design must be evaluated on a part-by-part basis.

Metal spray is not listed below, as this technology cannot be used with Telene resins. The metal grains resulting from the spraying process can be easily removed from the metal spray skin. This will create small undercuts, making part demoulding more and more difficult and leading to the metal spray skin destruction.

Commonly used materials for serial production are wrought aluminium alloys, cast aluminium alloys, and nickel shell.
Wood (or MDF (Medium Density Fibre))
Wood tools can be used for simple prototype runs of 10 parts or less. Advantages of wood tools include quick fabrication and low cost. However, surface quality and dimensional accuracy can be poor, and lack of thermal conductivity and moisture content can cause "wet" part surfaces. Draft angles should be generous, and part shapes should be kept simple since wood as the mould material does not resist material shrinkage as well as other materials do. Wood tools are often used to mould roughly shaped parts. The final shape is then achieved by machining the pre-shape.

Resin
Resin tools (either filled or laminated composite) can be used for prototyping as well as low volume production from 10 to 500 parts of low surface quality parts. Advantages over wood tooling include more complex shape capabilities and longer tool life. Advantages over metal tools include quicker fabrication and lower cost. However, resin moulds cannot be easily modified and surface quality of the moulded part is considered to be fair. Post curing of the tool when high temperature resin is used, is a critical step that can lead to mould distortion. Painted prototyping part can be made in resin tools, but extensive secondary finishing operations will be necessary to achieve typical transportation grade class A finishes. Thermal conductivity is typically low, requiring longer cycle times compared to metal moulds. Frequent mould repair is often necessary, sometimes after a minimum number of shots has been made. Parts designed for fabrication in resin tools should have a minimum 3° draft angle, generous radii, and should be of moderate complexity. Undercuts formed by loose pieces in the mould are possible. Resins such as epoxy, vinyl-ester, and in some cases polyester, have been used successfully.

Cast Aluminium
Cast aluminium tools are cheaper than machined wrought aluminium tools. Mould temperature control is better compared to wood and resin tools due to cast-in-place cooling passages and the thermal conductivity of aluminium. However, cast aluminium tools can have voids, porosity and surface defects that are translated into part surface problems. Sub-surface mould defects may be revealed during production, causing higher secondary operation costs. Cast aluminium tools are subject to shrinkage, and therefore dimensional accuracy could be poor, especially when producing a large tool. Local or overall machining of the tool can be done to improve dimensional accuracy; however the risk of exposing voids or porosity is increased. Plating can be used to increase surface hardness. In practice, cast aluminium is generally limited to the non-visible half of the tool, usually the core side, in combination with machined wrought aluminium, nickel shell or cast kirksite cavities.

Cast Kirksite
Kirksite is a cast alloy of zinc (92 - 94%) and aluminium (3.5 - 4.5%) which is less expensive and can be machined more easily than aluminium. The main advantage over cast aluminium is reduced porosity level, but porosity free surfaces cannot be guaranteed. Kirksite is therefore not recommended for parts with requirements for high quality finish. Temperature control is accomplished through cast-in-place steel tubing, with thermal effectiveness somewhat above nickel shell tooling, as the pipes can be located farther away from the surface. Mould changes can be accomplished fairly easily. Draft angles are normally recommended in the 3° range. Slides and loose pieces are possible, but cost may dictate other tooling
alternatives if tool movements become too expensive. The main drawbacks to the use of Kirksite tools are the increased weight (specific gravity approximately 6), and easily damaged tool surface due to the softness of the material.

Wrought Aluminium
Wrought aluminium is a widely used tooling material due to its uniform texture, ready availability, and ease of machining. High thermal conductivity and lighter weight as compared to steel also make it a good candidate for RIM tooling systems. Good to excellent surface quality can be obtained, and tool life of over 50,000 parts is possible. Almost any part design can be executed in wrought aluminium tooling including complex shapes, minimum draft angles, and undercuts formed by loose pieces (part) and / or slides. Cost of tooling is usually less than steel tooling, and can be less than nickel shell tooling for shallow parts optimally matching the sizes of commonly available aluminium blanks for tooling material. Some corrosion has been seen on tools made of alloys of the 2000 series containing a high level of copper, when associated with poor tool maintenance. Recommended alloys for tooling application are: 5083, 6061, 6082, 7075, or commercial trade names such as Duramould-2, Duramould-5, Alumould, and M1. Plating can be used to harden aluminium surface and increase chemical resistance. It is important to select a plating treatment that does not deteriorate the thermal conductivity of the tool, as the anodizing process does.

Nickel Shell
Nickel shell tooling is often a cost effective alternative tool for large or deep Class A parts. A master model is prepared via electronic data or by traditional pattern making means. Material and mould shrinkage is added during the model fabrication process. A metallic nickel layer is deposited on the model by electro deposition or vacuum deposition. Typical thickness of the nickel layer ranges from 4 to 10 mm, depending on the technology used. Soft models used in the electro deposition process are typically destroyed during removal from the nickel shell. More expensive aluminium models used in the vacuum deposition process can be re-used to generate a new nickel shell later on, if needed. The nickel shell is usually backed with metal filled epoxy, or concrete depending on expected tool life, cost constraints, and tool manufacturer’s preference. Mould temperature control is usually accomplished by copper tubing fixed or welded on the skin and embedded in the backing matrix of the tool. The temperature control is better than for epoxy tools, and can be as good as for all-metal tools with proper design and planning. Surface finish can be exceptional. Class A parts are paintable with little or no secondary finishing on the nickel shell moulded surface. The core side of the tool (the part of the tool forming the rear, backside or B side of the part) is usually made of cast aluminium to decrease the cost. Most draft angles can be accommodated, but manufacturers typically request approximately 3° of draft. Sharp edges or small radii are usually not recommended. Undercuts are possible, but are not normally recommended. The cost of numerous inserts and/or slides may negate the cost advantages of this tooling material. The inability to easily make changes or repairs is the major disadvantage. Therefore, if prototyping is required, less expensive tools are recommended. A combination of production nickel shell matrix and epoxy prototype core can be used, saving some of the total program costs. This technology is less expensive than steel tooling, and depending on the starting point (CAD data, existing master, or engineering drawings) can be less expensive than aluminium tooling especially for deeper class A or painted parts.
Steel
Machined steel moulds are usually a higher initial cost alternative than aluminium tooling due to longer machining times caused by the inherent hardness of steel. Steel also has lower thermal conductivity than aluminium, is considerably heavier, and more difficult to process. These disadvantages are offset by durability of a steel mould and its surface finish over long production runs. An ability to incorporate slides and moving cores is one of the major advantages of this mould material. Therefore, steel can be selected when parts are complex, requiring several cores, moving cores or when very high production volumes are involved. As they are subject to corrosive attack, steel tools should be plated with chrome or nickel, as the most common options.

Mould Material Comparison

<table>
<thead>
<tr>
<th>Materials</th>
<th>Projected Tool Life (No. of Parts)</th>
<th>Part Surface Quality</th>
<th>Mould Surface Hardness (*)</th>
<th>Heat Thermal Conduct. W/(m. °C)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>&lt;10</td>
<td>Poor</td>
<td>75-100 RM</td>
<td>0.11</td>
<td>Concept evaluation</td>
</tr>
<tr>
<td>Resin</td>
<td>&lt;500</td>
<td>Fair</td>
<td>80-110 RM</td>
<td>0.09</td>
<td>Prototyping, short production runs</td>
</tr>
<tr>
<td>Cast Aluminium</td>
<td>&lt;10,000</td>
<td>OK</td>
<td>60-100 BN</td>
<td>85 to 200</td>
<td>Production of non-class A parts</td>
</tr>
<tr>
<td>Wrought Aluminium</td>
<td>&gt;50,000</td>
<td>Good</td>
<td>60-90 BN</td>
<td>200</td>
<td>Series Production capability, most commonly used material</td>
</tr>
<tr>
<td>Nickel Shell</td>
<td>&gt;100,000</td>
<td>Excellent</td>
<td>90-120 BN</td>
<td>58</td>
<td>Economical in deep draw parts. Difficult to change or repair.</td>
</tr>
<tr>
<td>Steel</td>
<td>&gt;200,000</td>
<td>Excellent</td>
<td>130-160 BN</td>
<td>43</td>
<td>Very high volume, best surface (requires plating)</td>
</tr>
</tbody>
</table>

*: RM = Rockwell Hardness “M” scale; BN = Brinell Number

Shrinkage
To produce a part of certain “as designed” dimension, the appropriate tool dimensions must be somewhat bigger to compensate for both the polymerization shrinkage and tool thermal expansion. The polymerization shrinkage depends on the part thickness, and the tool thermal expansion depends on the tooling material and operating temperature. In practice, a shrinkage ratio, applied per half of the tool, takes into account both above-mentioned phenomena. The ratio is always a compromise that considers part’s thickness variation, as well as a requirement to match the surrounding components. Usually, the operating temperature of the tool is...
about 60°C/80°C for the core and cavity respectively, and the shrinkage ratio is usually different for the core and for the cavity to take into account the temperature difference. As the ratio applied on the core half is usually greater than the one used for the cavity such a tool design requires careful handling during storage and warm-up stage. Spacers keeping the mould open may be used to eliminate the risk of tool damage if mishandled.

An excel sheet is available upon request from Telene Technical Service. Some indicative values measured from a plate tool made of machined aluminium alloy are presented in Table 3. For greater thickness, shrinkage will depend more on process parameters and mould temperature control.

<table>
<thead>
<tr>
<th>Part thickness</th>
<th>% Shrinkage, from cold part to cold tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 4 mm</td>
<td>0.85 %</td>
</tr>
<tr>
<td>5 to 7 mm</td>
<td>0.90 %</td>
</tr>
<tr>
<td>8 to 12 mm</td>
<td>1.0 %</td>
</tr>
</tbody>
</table>

Variable thickness of the part can itself be a cause of additional deformation due to differential shrinkage across the part.

**Heating / Cooling Line Design**

General quality of a Telene part depends mostly on thermal regulation that defines such temperature related factors as Telene components reaction, shrinkage/distortion, surface quality, cycle time, demoulding Behaviour.

Typical mould temperature is 70 °C to 80 °C on the cavity, and 55°C to 65°C on the core. The gate and runner area should also be included in the heating / cooling system design. Surface quality, demoulding Behaviour, and cycle time can be affected by poor temperature control of the tool.

Different heating / cooling line designs have been successfully tested for tools of different materials and constructions.

If the lines are located very close to the mould surface, it is always preferable to reduce the line diameter and to increase the number of lines, in order to avoid hot spots that can be seen on the part surface. Lines could be as close as 50 mm to each other. Best results have been obtained when connecting the water lines through a distribution manifold that creates a parallel water flow.

For machined tools, recommended dimensions for water channels sizing and positioning are as follows:

- 25-50 mm from the print surface
- Space between channel and print surface must be as homogenous as possible
- Channel diameter: usually around 16mm
- Space between channels: 70 to 100mm

For casting tools, water pipes should be used, and are typically smaller diameter and spaced closer together. The distance from the print surface is usually less than 25mm.
Mould Layout
For mould layout, the design engineer needs to consider location of the mixing head and gate, flash and gasket, vents, and centring devices.
A typical layout is shown at Figure 32 through Figure 34.
Guide Pins
All moulds should have guide pins installed to ensure proper core and cavity alignment, thus preventing any damage to the mould during closing and opening. They need to be designed and located to minimize stresses induced by running the tool with a temperature differential between the two halves. Therefore, it is recommended to use rectangular guides so-called “square guide bar” or “square interlocks” that provide guiding in only one direction and locate them as close as possible in the centre of the tool sides. We have found that it is more convenient to have the male portion of the guide located on the upper half of the mould. A typical design is shown on Figure 35.
**Parting Line**

Mould cost and part quality are very sensitive to parting line location. Venting and demoulding as well as potential undercuts and class A surfaces are the main factors to consider. In some cases, local limited undercuts can be demoulded by taking advantage of the Telene polymer shrinkage characteristics. Contact Telene Technical Service for design assistance in that case.

For a flat part, the parting line will not have a serious effect on the mould cost, but for a 3D shaped part, the parting line can impact the amount (volume) of the mould material needed. However, the primary consideration for the choice of a parting line should be given to mouldability and quality of the part.

A typical design of the parting line for a nickel shell tool is shown at

![Diagram of parting line](image)

**Figure 39.**

**Gasket**

The entire mould cavity, including the vents and mixing head, should be held within a rubber gasket. This increases internal pressure in the tool at the end of the shot, preventing any dissolved nitrogen from coming out of solution. Besides, the gasket prevents air aspiration around the mixing head and runner. Selective openings in the gasket may be used to facilitate venting control.
The groove cross section area should be larger than that of the gasket, including tolerances on the gasket dimensions. Sharp corners (either horizontal (Figure 37) or vertical (Figure 36)) on the groove design should be avoided as they lead to damage to the gasket, as well as to loss of sealing in case of a corner between the core and cavity. In the case of a vertical corner, create at least a 5 mm radius in the parting line to maintain sealing (see Figure 36), or move the gasket groove further from the part to avoid the sharp corner. A draft minimum of 7° should be kept on gasketed vertical walls to prevent gasket damage when closing the tool.

Compression height depends on the precision of the mould production process. Typical compression height is 0.5 mm for a mould of wrought aluminium alloy, and is higher for casting technology.

All types of conventional rubber gasket can be used depending on mould temperature. The gasket hardness depends on its diameter. Typical hardness is 70 shore A for 5 mm diameter, whereas a hardness of 40 shore A is commonly used for 8 mm diameter.

In the case of venting adjustments during moulding, a small piece of the gasket can be cut out or flattened to create a local vent. Therefore hollow gaskets are not recommended as the hollow section will be filled with Telene during the shot, if the gasket is cut out or flattened down. This will result in a longer time needed to prepare the mould between shots, as well as in variations of venting from one shot to another. A typical design is shown on Figure 38. Groove cross section must be squared and slightly larger than the gasket's, to reduce the risk of gasket damage. The gasket groove dimensions are shown for a 5.0 mm diameter rubber seal. Groove dimensions should be modified to fit with other seal diameters. The groove...
cross section should be at least equal to the maximum gasket cross section (nominal section area plus tolerance). For this reason square gasket profiles are not recommended.

**Flash Design**

Mould flash areas and sealing surfaces are critical to successful RIM moulding. A small flash area around the part periphery allows a larger processing window. This flash normally serves to capture bubbles, allows some parting line venting, and can minimize mould cleaning frequency. Lastly, flash helps in the demoulding process.

Flash is specifically required in areas where the flow ends perpendicularly to the edge of the part. It is important to have flash thick enough to stay with the part during demoulding to avoid time-consuming mould cleaning operations, and yet designed to be easily removable during trimming.

Flash shall be machined on the core side in order to ease mould cleaning and part deflashing. A typical design utilizing a 5mm gasket is shown at Figure 38 and

![Diagram](attachment:flash_design.png)

Figure 39.
The location where flash needs to be foreseen depends on the geometry of the part. In areas where a substantial amount of venting is needed, a reservoir (dumpwell) can be milled into the mould. The flash would then only channel the air towards the reservoir. The reservoir does not necessarily need to be fully filled, but it allows a larger processing window to solve venting issues.
The designed flash around the perimeter of the part should end just prior to reaching or contacting the gate. A direct connection between the flash and the gate will have a detrimental effect, and may lead to air entrapment in the part.

Vents
There are a number of different vent designs used in RIM technology. With Telene, one wants to eliminate the air entrapped in the mould. Vents should be located on the core side close to the areas to be filled last, with respect to gate location and tilt angle. As Telene does not expand during polymerization no backpressure is developed in the tool when filling stops. Therefore, provision of sufficient backpressure during filling helps to fill small details difficult to vent locally.

Vents provide for internal pressure to be developed at the end of the shot when encompassed by the gasket. Backpressure and venting are controlled by local openings in the gasket between the cavity and reservoirs if necessary.

Assuming the cavity is in the lower part of the mould, vents are usually machined in the core side to ensure that air is trapped in the vents by excess material, thus reducing or eliminating the risk of air bubbles migrating back into the part at the end of the shot. Vents in the core are important for the Telene RIM-process particularly when parts are moulded horizontally. After opening the mould, the excess material from the reservoirs will remain on the cavity side protruding from the parting line surface, making it easier to demould.

Typical vent volume amounts to 5% of the part volume, which provides sufficient backpressure to ensure part quality.

On very large parts, vent volume is often reduced to avoid excess waste material in reservoirs. The backpressure in the tool during filling can also be controlled by connecting the vent to a backpressure relief valve.

A typical design is shown on Figure 40.

![Figure 40](image)

Moulded Openings
Open areas moulded in place require special care. Open areas can range from a simple small hole to a large area, as in the case of an air intake, access door, grill location, etc.
Ideally, the inner edges should have flash provided at the location where the anticipated flow ends perpendicularly or almost perpendicularly to the moulded opening. Depending on the space available a reservoir and a gasket groove should be integrated to prevent knitting flow fronts from pushing air bubbles forward into the part along the flow path. By providing a reservoir in the shutoff area, air bubbles formed by the knitting flow fronts will instead be directed away from the flow path and moulded part. In the case of a large reservoir volume, it may turn to be desirable to connect the vent to the atmosphere through the mould core, to prevent pressurized air in the closed reservoir to re-enter the part.

A typical example of vent design for a horizontal cut-out is shown on Figure 41.

![Figure 41](image)

Design of cut-outs on a sloped wall is similar to that of horizontal cut-outs. If the wall is becoming closer to vertical, the internal reservoir and gasket can be omitted. Instead, design flash in the open area to a minimum thickness of 0.5mm to provide local venting. This type of cut-out is prone to bubbles on the edges, therefore it is recommended to round over the edges with as large a fillet radius as allowable.

Almost vertical contacts or shut offs between aluminium surfaces of the mould can be an issue and may result in premature wearing of the mould. Therefore, a minimum $7^\circ$ draft angle should be incorporated, otherwise it is often preferable to mould the part solid and trim or machine the opening during finishing operations.

For further information on a case-by-case basis, please contact your Telene technical representative.

**Handling Devices**

All moulds should be designed for ease of installation and removal by using forks or a crane. Both halves of the tool should be secured by appropriate clamps or metal brackets.

**Demoulding Behaviour**

Due to curing, the part has a natural tendency to stay on the warm side of the mould. When moulding a part that requires high surface quality on one side, the warm face on the tool must be the show face of the part. Usually this is the cavity side.

After injection, normal operations are as follows:

- Opening of the tool.
- Removal of the peripheral flash, allowing the linear shrinkage to take place.
• Putting inserts in place for the next moulding, if applicable. This prevents inserts from accidentally falling onto the mould surface. Instead, they would fall onto the part waiting to be demoulded.
• Removal of the part using the flash to extract the part from the cavity.

The Telene polymer achieves all its mechanical and thermal properties in the tool during the curing step. Therefore, special care should be taken when designing a tool to anticipate potential demoulding problems due to the combination of shrinkage contraction and high modulus. Because of their rigidity, Telene parts cannot be stripped from the cavity like PU ones.

As a rule, demoulding problems occur when the part sticks to the tool due to shrinkage. Various shapes can create such sticking, e.g. bosses, inserts, ribs, and grills created on the cavity side. In this case, ejectors need to be used to help demoulding, unless generous draft angle can be arranged at these areas. As the demoulding force is directly related to part shrinkage, the distance between potential locking areas located on the cavity side is a critical point when considering the need for ejection.

Friction induced by shrinkage should be reduced as much as possible. Therefore, a good mould surface finish in critical geometry areas is important. For a core, 240-320 grain sand paper (US specification approximately SPI B3) or equivalent treatment is recommended. For cavity, 400 grain (B2) is typically used along with 600 grain (B1) as needed for local areas.

In many cases where difficult part geometry is encountered, compressed air can be used to decrease the stripping (demoulding) force required.

Demoulding Behaviour is illustrated on Figure 42 and Figure 43.
Figure 42 demonstrates the tendency of the part to stick to the hotter part of the tool. Figure 43 shows how demoulding behaviour depends on shape of the part.

**Drag Plate/Stripper Plate Operating Concept**

A concept of a drag plate (also called a stripper plate) can be used to facilitate demoulding. The following illustrations demonstrate operation of a drag plate.

When the mould is closed, the plate is forced against the core by the hydraulic cylinders (Figure 44).

While opening the mould, the cylinders force the plate down to maintain the part in the core while the press opens (Figure 45).
When the press opens completely, the part stays on the core with flash exposed outside (Figure 46).

Part’s shrinkage helps to easily demould it from the core (Figure 47). Various vents are cleaned and flash is removed before sticking the plate to the core and closing the mould again for the next shot.
Air Ejection
Another means to facilitate demoulding that can be used is air ejection of the part. Figure 48 and Figure 49 demonstrate operation of a typical air ejector. Self-contained “poppet”-style are also commonly used, and are readily available through mould component supply companies.
Air inlet - 6 bars
Switch on for demoulding

Position during Demoulding

Figure 49
3.3 Mould Gate Design for TELENE Resins (1600 Series)

Gate
In the reaction injection moulding process, impingement mixing occurs in the mixing chamber of the high-pressure mixhead. This turbulent mix must then be transformed into laminar flow as the resin enters the mould cavity in order to minimize moulding defects. Transition from turbulent to laminar flow is accomplished by a gate system located between the mixhead and the mould cavity. As Telene components have the same viscosity, they are easy to mix and do not require high mixing pressure or a complex after mixer.

There are 2 major types of gates for RIM: a direct gate & a film gate

- The direct gate type is not recommended for Telene resins.

If there is no other economical way to design the gate, the direct gate can be used under the following conditions:
- part thickness in the gate area should not be greater than 3 mm;
- a very good seal between the mould and the mixhead is needed in order to prevent air suction in the gate;
- an L-shape mixhead which provides laminar flow from the mixhead, is strongly recommended.

- The film gate is the most recommended type of gate for Telene.

There are several types of film gate that can be used:
- rod or sprue gate;
- dam gate or coat hanger gate;
- fan gate.

The most common gate type for Telene is the rod gate (Figure 50). Each of these gates should be used in conjunction with
- a flow restrictor, which should be located as closely as possible to the mixhead, and
- a runner which transports the liquid resin to the gate in a laminar flow.

![Diagram of Mould Gate Design for TELENE Resins](Figure 50)
Dimensions of the flow restrictor depend on the mixhead size whereas the design of the gate and the runner depends on the gate location and the injection output.

Important parameters to ensure backpressure in the gate and laminar flow when material enters the part:

- Flow velocity in the gate:
  - < 4 m/s for thin parts (wall thickness is < 6 mm next to the gate)
  - < 2 m/s for thick parts (wall thickness is > 6 mm next to the gate)
- Reynolds number calculated on the flow leaving the gate, Re must be >10
- Film gate to manifold pressure drop ratio at least 1.5

**Flow Restrictor**
A flow restrictor prevents material jetting down to the runner and provides backpressure in the mixhead which promotes complete and thorough mixing.

The type of flow restrictor depends mainly on the way the mixhead is connected to the runner.
If the mixhead is mounted at a 90° angle to the runner axis, it can be a disc like area directly below the mixhead. See Figure 51 for an example of disk like transition and related calculation sheet.
If the mixhead runs directly end-on to the runner the restriction can be a flow diverter (Figure 52), an after-mixer or a sharp 90° angle.
Disk Transition Calculation

Design Rules:

**Part name**

Objective of this sheet is to provide dimensions for the disk used to connect mixhead mounted vertically
to the end of the runner calculated with the "Rod gate." calculation sheet

Two design rules are applied:
1. In order to maintain back pressure in the mix head, the maximal cross section of the disc is reduced to 3/4 of the mix head nozzle section
2. Transition section is 5% higher than the runner cross section

For the ease of understanding the notation of the the "rod gate." calculation sheet are maintained
MR and MT refers respectively to the runner radius and depth as calculated previously

---

Step 1: calculation of the transition section

<table>
<thead>
<tr>
<th>Runner radius (MR) (mm)</th>
<th>Manifold Thick. (MT) (mm)</th>
<th>Runner projected radius (RD) (mm)</th>
<th>Runner section mm²</th>
<th>Transition section (A) mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.0</td>
<td>10.7</td>
<td>12.8</td>
<td>206.8</td>
<td>217.1</td>
</tr>
</tbody>
</table>

Step 2: calculation of the maximum disk radius RD

Enter the mix head diameter and the foreseen disk thickness (typically 2.5 or 3.0 mm) in the cell in green

<table>
<thead>
<tr>
<th>Mix head diameter (mm)</th>
<th>Piston section mm²</th>
<th>Disk vertical section mm²</th>
<th>Disk thickness t (mm)</th>
<th>Disk diameter D (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>201</td>
<td>151</td>
<td>3</td>
<td>50</td>
</tr>
</tbody>
</table>

Step 3: calculation of the transition section for a set of disk radius R and distance d

Enter estimated R and d values in the cell in green (R is typically = or > to R), d should be less than R+R

Compare with transition section A calculated in Step 1 and adjust R or d accordingly.

<table>
<thead>
<tr>
<th>R mm</th>
<th>R_R</th>
<th>d mm</th>
<th>A mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.8</td>
<td>15</td>
<td>&lt; 28</td>
<td>210</td>
</tr>
</tbody>
</table>
Flow restrictor: Flow diverter

Runner
The runner is a feeding channel connecting the mixing head and the gate. The runner can typically be a semi-circular, or a semi-lenticular channel, and the latter is a better choice for easier demoulding.

Gate Location
The gate is better to locate close to the lowest point of the tool (taking into account possible mould tilting) next to a vertical wall of the part to minimize flow effect on part surface quality close to the gate. If this is not possible, it is recommended to consider the gate connected to an edge of the part on a B-side of the part.
While selecting a place for the gate, it is recommended to foresee potential location of vents. Ribs and alike geometrical features ideally should be oriented along the flow from the gate.
**ROD GATE DESIGN SHEET**

**Design Rules:**

- Reynolds number in the gate <10
- Velocity in the gate:
  - < 4 m/s for thin part (3 to 6mm)
  - < 2 m/s for thick part (7 and more)
- Gate to Distributor channel pressure drop ratio > 1.5

**Injection Parameters**

<table>
<thead>
<tr>
<th>Injection Weight Kg</th>
<th>Part Thickness mm</th>
<th>Injection rate (g/s)</th>
<th>Injection Time (s)</th>
<th>Re number</th>
<th>Gate Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.365</td>
<td>3</td>
<td>200</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

**Gate Dimension**

<table>
<thead>
<tr>
<th>Thickness (T in mm)</th>
<th>Gate width (L in mm)</th>
<th>Gate length (L0 in mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0.1</td>
<td>&gt; 5</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>120</td>
<td>30</td>
</tr>
</tbody>
</table>

- Theoretical Processing Window is range of injection rates with light green cells.
- Practical processing window depends also on temperatures, pressures in the process as well as filling length.

<table>
<thead>
<tr>
<th>Gate cross section (mm²)</th>
<th>Gate velocity (m/s) in the gate</th>
<th>Re number</th>
<th>Gate pressure (Bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>1.5</td>
<td>4.62</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**Distributor channel dimensions**

<table>
<thead>
<tr>
<th>Radius (MM)</th>
<th>Manifold Thick. (MT)</th>
<th>Equivalent Hydraulic Runner section (mm)</th>
<th>Runner section (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>6.2</td>
<td>3.8</td>
<td>75.0005712</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel cross Section (mm²)</th>
<th>Channel pressure (Bar)</th>
<th>Gate to Channel Drop ratio (&gt;1.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>1.0</td>
<td>1.57</td>
</tr>
</tbody>
</table>
ROD GATE DESIGN

Section 1

Section 2

Figure 54
Coat-Hanger Gate Calculation

See Figure 55 and Figure 56 for an example of rod gate design sheet and illustration of the rod gate design and dimensions.

### Design Rules:

<table>
<thead>
<tr>
<th>PART ID</th>
<th>Reynolds number in the gate</th>
<th>&lt;10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity in the gate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 4 m/s for thin part</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 2 m/s for thick part</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gate to Distributor channel pressure drop ratio</td>
<td>&gt; 1.5</td>
</tr>
</tbody>
</table>

### Injection Parameters

<table>
<thead>
<tr>
<th>Injected Weight Kg</th>
<th>Part Thickness mm</th>
<th>Injection rate ( g/s )</th>
<th>Injection Time ( s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>200</td>
<td>25</td>
</tr>
</tbody>
</table>

### Gate Dimensions

<table>
<thead>
<tr>
<th>Thickness ( mm )</th>
<th>Gate width ( L ) ( mm )</th>
<th>Gate length Lo ( mm )</th>
<th>&gt; 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>120</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gate cross Section ( mm² )</th>
<th>Gate velocity m/s</th>
<th>Re number in the gate</th>
<th>Gate pressure Drop (Bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>1.7</td>
<td>4.62</td>
<td>1.4</td>
</tr>
</tbody>
</table>

### Manifold and Runner dimensions

<table>
<thead>
<tr>
<th>Manifold Radius (MR) ( mm )</th>
<th>Runner Radius (RR) ( mm )</th>
<th>Depth ( Y ) ( mm )</th>
<th>Curv. Rad. 1 ( R1 ) ( mm )</th>
<th>Curv. Rad. 2 ( R2 ) ( mm )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>8</td>
<td>17</td>
<td>114</td>
<td>5.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manifold Thick. ( MT ) ( mm )</th>
<th>Runner Thick. (RT) ( mm )</th>
<th>Equivalent Hydraulic Radius (mm)</th>
<th>1/2 Channel length</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5</td>
<td>6.6</td>
<td>2.8</td>
<td>55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manifold cross Section ( mm² )</th>
<th>Channel press. Drop (Bar)</th>
<th>Gate to Channel Press. Drop ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>0.8002</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Telenor - 98/06
Figure 56
3.4 Multiple Cavity Mould Design

Multiple cavity moulds are often used when weight of the single part is too small for the available RIM-equipment. In that case, a multiple cavity mould will allow getting around very small injection time (< 3 sec) as well as reducing the moulding fixed cost per part. Number of prints needs to be carefully evaluated, as too many prints will increase material loss in the runners and demoulding time.

For general mould layout, the same rules apply to each of the print as to a single print tool, including the gasket, flash, reservoirs and gate positioning. Reservoirs must not be shared between the neighboring prints, as this would lead to air flowing back from one print to the other in case of back pressure difference. Making decision as to gate location is more difficult as one has to consider proximity of other prints next to the gate.

All the prints together must be surrounded by the gasket, oriented to ensure proper filling and venting. If necessary, a compromise between mould material saving and desired gate location should be found.

Except for the machine output, the process window (the range of values taken by the various parameters controlling the process that produces good quality part) is usually reduced.

The main runner splits in as many runners as the number of prints in the mould. The gates must be sized to maintain backpressure in all the channels that requires a special calculation. The basic rule is:

main runner section = (sum of all split runners)×1.05

Multiple print gate design is relatively simple to calculate in the case of symmetrical parts, for example left and right panels, or when print have similar weight. It is much more complicated in the case of more than 2 prints or when prints are of very different weight.

For an example of the calculation sheet for a 2 print mould gate see Figure 57, and for an example of multiple print mould layout see Figure 58.
### MULTIPLE PRINTS ROD GATE DESIGN SHEET

#### Design Rules:
- Reynolds number in the gate: < 10
- Velocity in the gate: < 4 m/s for thin part (3 to 6 mm)
- > 2 m/s for thick part (7 mm and more)
- Gate to Distributor drop ratio: > 1.5

#### Injection Parameters

<table>
<thead>
<tr>
<th>Processing Window</th>
<th>Part 1</th>
<th>Part 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injection Time</td>
<td>32.3</td>
<td>48.0</td>
</tr>
<tr>
<td>Injection Flow</td>
<td>0.77</td>
<td>0.58</td>
</tr>
<tr>
<td>Gate Velocity</td>
<td>0.55</td>
<td>0.85</td>
</tr>
</tbody>
</table>

#### Total Output

<table>
<thead>
<tr>
<th>Total Output</th>
<th>Injection</th>
<th>Part Thickness</th>
<th>Filling Balance</th>
<th>injection</th>
<th>Single cavity</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g/s)</td>
<td>Vein (Kg)</td>
<td>(mm)</td>
<td></td>
<td>(g)</td>
<td>(g/s)</td>
<td>(s)</td>
</tr>
<tr>
<td>1200</td>
<td>7</td>
<td>6</td>
<td>0.72</td>
<td>863</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>1200</td>
<td>2.7</td>
<td>6</td>
<td>0.28</td>
<td>334</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

#### Gate Dimension

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Gate width (L) (mm)</th>
<th>Gate length (mm)</th>
<th>Gate cross section (mm²)</th>
<th>Gate velocity (m/s)</th>
<th>Flow number in the gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>356</td>
<td>45</td>
<td>420</td>
<td>2.1</td>
<td>6.66</td>
</tr>
<tr>
<td>12</td>
<td>150</td>
<td>40</td>
<td>190</td>
<td>1.7</td>
<td>5.79</td>
</tr>
</tbody>
</table>

**Theoretical Processing Window** is range of injection rates with light green cells.

**Practical Processing Window** depends also on temperatures, pressures in the process as well as filling length.

#### Distributor Channel Dimensions

<table>
<thead>
<tr>
<th>Channel</th>
<th>Pressure drop (bar)</th>
<th>Gate to distributor Drop ratio (&gt;1.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Disclaimer:**
The information contained herein is believed to be reliable, but no representations, guarantees or warranties of any kind are made as to its accuracy, suitability for particular applications or the results to be obtained.

Usage of this sheet is done under the sole responsibility of user.

---

**Figure 57**
Figure 58

Runner 1

Main runner

Runner 2

Gate 1

Gate 2

Part 1

Sealing gasket

Part 2

Flash and reserves not represented
A List of Suppliers
This section has some useful links to companies which have already worked with Telene in some way. The companies’ locations and telephone numbers can best be taken from their website, since that’s the most accurate data. In case we have the name of a contact person who works/worked on Telene projects, it will be stated below. This will reduce your time on the phone trying to find the right person.

1. Cleaning products before painting

ZEGER+GMELIN  
www.zeller-gmelin.de
CONDOR OIL and CHEMICAL CO  
www.condoroilandchemical.com

2. Paint Systems

AKZO  
http://www.akzonobel.com  Go to the coatings division.
AXALTA  
http://www.axaltacs.com
BASF COATINGS  
http://www.basf-coatings.com/global/ecweb/en/content/index
BECKER  
http://www.beckers-group.com/
TIKKURILA  
http://www.tikkurila.com
MANKIEWICZ  
http://www.mankiewicz.de
PPG INDUSTRIES  
http://www.ppg.com  Go to “Industrial Coatings”
SCHAEPMAN  
http://www.schaepman.nl
SHERWIN-WILLIAMS  
http://www.sherwin-williams.com

Water Based Paint system
TEKNOS  
http://www.teknos.fi
GROSS &PERTHUN  
http://www.gross-perthun-lackfabrik.de
WORWAG  
http://www.woerwag.de

3. Adhesive Systems

EBS Acralock  
http://www.acralock.com
HENKEL  
http://www.henkel-adhesives.com
ITW PLEXUS  
http://www.itwplexus.com/ Also available in France via Samaro (www.samaro.fr)
JACRET Technologies  
http://www.jacret.com/
4. Fillers & Repairing Accessories

DEVCON http://www.devcon.com
3 M http://www.3m.com

5. Mould Polish

I.C.R. http://www.icrprint.it

6. Mould Release Agent

F.IN.CO s.r.l
via Assiano, 11
I - 20019 SETIMO MILANESE (MI)
Tel (00 39) 02 335 122 89
http://www.fincosrl.it/

7. Mould Makers EMEA

CERO - France
BP 335 – Z.I Rue des Plantes
85303 Challans Cedex
Tel : +33 (0)2 51 49 79 10
http://www.cero.fr
CI-ESSE - Italy
Via Marsala 34, 20052 Monza (Milano)
Tel: +39 039 2007881
http://www.ci-esse.eu/en

C.M.O - France
Z.I. La Courbière
49450 SAINT-MACAIRE-EN-MAUGES
Tél : 02 41 55 34 43
Fax : 02 41 55 34 57
Email : cmoetudes@gbusiness.fr
http://www.moule-outillage.com

ELKINGTON BROTHERS – United Kingdom
Baltimore Road, Great Barr, Birmingham B42 1DD
Tel: 0121-358 2431, Fax : 0121-358 7527
www.elkingtonbrothers.com

FORMEC – Sweden
Fabriksgatan 6, Skövde
Tel: +46 500 434285
http://www.formec.se

LANULFI S.R.L. - Italy
Via dell’Industria n. 1 –
36010 Monticello Conte Otto VI
Tel:(+39) 0444 1831163
www.lanulfi.com
8. Mould Makers North America

BEVERLY PATTERN INC - USA
31 Park St.
Beverly, MA 01915
978-927-0052
978-927-8806 Fax
www.beverlypattern.biz

WESTOOL CORPORATION - USA
7383 Sulier Dr
Temperance, MI 48182
734-847-2520 ph
734-847-9180 fax
www.westools.com
PARAGON DIE AND ENGINEERING - USA
5225 33rd St. SE
Grand Rapids, MI 49512
Phone: (616) 949-2220
Fax: (616) 949-2536
www.paragonde.com

MODEL DIE AND MOULD INC - USA
3859 Roger B Chaffee Memorial Dr SE
Wyoming MI 49548, USA
Phone: 616-243-6996
Fax: 616-243-9874
www.modeldie.com

CENTURY TOOL AND GAGE - USA
200 S. Alloy Drive
Fenton, MI 48430
810-629-0784
810-629-9284 Fax
www2.centurytool.com

WEBER MANUFACTURING TECHNOLOGIES INC - CANADA
16566 Hwy 12
Midland, Ontario, Canada
L4R 4L1
705-526-7896
705-526-3818 Fax
www.webermfg.ca
FET ENGINEERING INC - USA
903 Nutter Dr - Bardstown, KY 40004
502-348-2130
502-348-7040 Fax
www.fetusa.com

9. Inserts

TAPPEX www.tappex.co.uk
STANLEY Eng. Fastening www.stanleyengineeredfastening.com
Tri-Star Industries www.tristar-inserts.com
VMP Inc. www.vmpinc.com
Penn Engineering www.pemnet.com
Yardley Products www.yardleyproducts.com
Rotaloc www.rotaloc.com

10. DCPD Vapour Adsorption

ALPHA-CHEM http://www.alpha-chem.fr/
NORIT Activated Carbon http://www.norit.com/

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3. 2007_11 TELENE 1650 test - 60°C flexural and tensile EN FR
4. Impact resistance of Telene at various temperatures
5. Ageing properties
7. Fire behaviour
8. Heat Capacity
10. 2014_03 Fatigue Test JIS K7119