Single-screw extruders with a compression ratio of 1:2 to 1:3, preferably 1:2.5, are recommended for processing of Elastollan. Our experience shows that three section screws with a L/D ratio of 25 to 30 are most suitable. Three-section screws should have a continuous, constant pitch of 1.1D. The radial clearance between screw and barrel should be 0.1 to 0.2 mm. For processing of Elastollan multi-zone screws, e.g. barrier screws (undercuts ≥1.2 mm) have also proven suitable. Short screws with a high compression ratio are unsuitable. Barrels with a grooved feeding zone have proven successful in practice, and provide the following benefits:

- constant feeding characteristics
- improved pressure build-up
- increased output

If grooved feeding zones are used, cooling is necessary. It is also advisable to use a screw with a mixing section, in order to improve homogeneity of the melt. Such mixing sections should, however, be designed to avoid shear degradation.
Use of breaker plates and screen packs is recommended. Good results have been obtained from a combination of two screens of 400 mesh/cm² as backing plates and two fine screens of 900 mesh/cm². Finer screens may be necessary for certain applications (e.g. film production).

Depending on screw diameter and type of die, breaker plates should have holes of 1.5 to 5 mm in diameter.

Extrusion of thermoplastic polyurethane requires a more powerful motor than for other thermoplastics. Power consumption is between 0.3 and 1 kWh per kg output, depending on screw design.

Melt pumps have proved successful for continuous melt flow.

---

### Recommended temperatures for processing in °C

<table>
<thead>
<tr>
<th>Shore hardness</th>
<th>Cylinder</th>
<th>Heating zones</th>
<th>Nozzle</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 to 70 A</td>
<td>140–175</td>
<td>160–175</td>
<td>160–165</td>
</tr>
<tr>
<td>75 to 85 A</td>
<td>160–200</td>
<td>175–200</td>
<td>170–205</td>
</tr>
<tr>
<td>90 to 98 A</td>
<td>170–210</td>
<td>200–220</td>
<td>190–210</td>
</tr>
</tbody>
</table>

Table 6

### Relation: max. screw speed – screw diameter

- **Max. circumferential speed**: 0.15 m/s

Fig. 18

---

### Processing Parameters

**Processing Temperature**

The following temperature ranges, which are dependent on the hardness of the Elastollan grades are recommended:

<table>
<thead>
<tr>
<th>Shore hardness</th>
<th>Cylinder</th>
<th>Heating zones</th>
<th>Nozzle</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 to 70 A</td>
<td>140–175</td>
<td>160–175</td>
<td>160–165</td>
</tr>
<tr>
<td>75 to 85 A</td>
<td>160–200</td>
<td>175–200</td>
<td>170–205</td>
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<tr>
<td>90 to 98 A</td>
<td>170–210</td>
<td>200–220</td>
<td>190–210</td>
</tr>
</tbody>
</table>

### Screw Speed

Since thermoplastic polyurethanes are shear-sensitive, excessively high screw speeds may lead to a reduction in product properties.

Fig. 18 shows the relation of max. screw speed to screw diameter.
**Melt Pressure**
Melt pressure is dependent on the head-design and the die gap, and on melt temperature. Normally the maximum pressure at the adapter is 300 bar, however, peaks of up to 1,000 bar can occur at start-up. Thus, for safety at start-up, a variable screw drive is recommended. If needed, starve feeding is possible.

**Cleaning of the Extruder**
When changing grade or after several days of continuous operation, cleaning of the extruder is recommended.
Polypropylene or HDPE, which require higher processing temperatures, are suitable for this purpose. In addition, it is sometimes necessary to use a purging compound.

**Die Design**
To ensure a constant melt flow, it is important to operate with narrow cross-sections and to avoid dead spots in the die. This will cause automatic self-cleaning of the die.

In all other respects, guidelines for head design are the same as for the extrusion of other thermoplastics.

Fig. 19 shows examples of typical dies:
**Die Design**

For extrusion of tubes and profiles, dies with a relatively long land are recommended. This reduces the shear stresses, thus permitting a constant discharge. Land length should be two to four times nozzle diameter.

---

**Cooling and Calibration**

Freshly extruded thermoplastic polyurethanes have a relatively low melt strength and are therefore prone to distortion. This necessitates effective cooling. The water bath should be close up to the extruder head. Chilled water is preferred. Instead of cooling baths a cooling line with spray nozzles is also suitable.

The length of cooling bath required for Elastollan grades generally exceeds the requirement for other thermoplastics. The length depends on the grade of material, extrudate shape and section, and haul-off speed.

Due to high coefficient of friction, compared to general thermoplastics, active calibration of thermoplastic polyurethane is not possible.

Calibration devices as shown in diagrammatic view in Fig. 21 are suitable to support the extrudate.

It is essential to provide a lubricating film of water between the surface of the extrudate and the calibrating die. This can be achieved by a water spray ring located before the entry into the cooling bath.

Fig. 22 describes the layout of a tube extrusion line for Elastollan.
Processing Extrusion

Cooling and Calibration

Cooling bath for tube extrusion

Fig. 22

Extrusion techniques

Tubes and Profiles
Tubes and profiles are mostly extruded horizontally. However, thin-walled tubes, e.g. fire-hose linings, are generally extruded vertically.

It is necessary to supply supporting air to prevent collapsing of the tubes.

To assist shape stability for hollow shapes it is recommended to use vacuum.

The guide rollers in the cooling bath should be matched to the shape of the extrudate.

Sheathing
Sheathing of cables, hoses, etc. is carried out by using a crosshead (see Fig. 23), equipped with a pressure or tube die (see Fig. 19). The inner-core which is to be sheathed must be dry and free from grease, in order to avoid blistering after extrusion and to ensure good bonding.
**Film**
Special Elastollan grades are suitable for the manufacture of blown film.

Fig. 24 shows, in diagrammatic form, a film blowing head.

Films of greater wall thickness can be produced by the flat film extrusion process using a sheet die (see Fig. 25); normal extrusion grades are suitable.

**Blow moulding**
Blow moulded articles can be manufactured from selected Elastollan grades using conventional blow moulding machines.

To improve ease of demoulding, the use of a mould with roughened surface (approx. 35 µm) is recommended. Wall thickness control is necessary to compensate for elongation of the parison. Fig. 26 shows a torpedo head for blow moulding.
Special Processing Methods

Following special methods are suitable for Elastollan:

**Coextrusion**

To achieve a combination of properties of different thermoplastics in one processing step.

For bonding reasons materials have to be compatible. Compatibility can differ between Elastollan ether and ester types.

**Thermoplastic Foam Extrusion**

For weight reduction and to achieve special properties.

Two methods are applicable:

- Chemical expanding of the melt by addition of expanding agent with conventional extruders; foam density between 0.4 and 1.0 g/cm³ is attainable.
- Physical expanding of melt by injection of gas into the extruder. Foam density below 0.4 g/cm³ is attainable. The structure of foam is controlled by a nucleating agent.

Trouble Shooting Guidelines

<table>
<thead>
<tr>
<th>Trouble shooting guidelines</th>
<th>Melt/ Cylinder temperature</th>
<th>Die temperature</th>
<th>Die pressure</th>
<th>Screw speed/ Output</th>
<th>Land length</th>
<th>Homogenisation</th>
<th>Moisture content</th>
<th>Material contamination</th>
<th>Cooling feeding zone</th>
<th>Lubricant</th>
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<tr>
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</table>

▲ Increase to solve problem
▼ Reduce to solve problem
★ Increase or reduce to solve problems

Table 7