

## **PROCESSING OF FREE-FLOWING THERMOSETTING COMPOUNDS**

### **I. INJECTION MOULDING**

#### **1. Injection Moulding Machines**

Thermosetting moulding compounds may be processed on all standard injection moulding machines equipped with a thermoset unit.

Standard screws for thermosets normally have a compression of 1:1.2 and the length:diameter ratio usually between 15 - 19.

The cylinder should be equipped with a minimum of two separately regulated heating zones (see figure 1).

#### **2. Processing of Raschig moulding compounds**

Please see table 1 for the parameters for injection moulding processing of our moulding compounds

- RALUPOL (UP)
- RESINOL (PF)
- MELOPAS (MF+MPF)
- AMPAL (MPV)

#### **3. Moulds**

##### **3.1 Sprue and Runner Systems and Gates**

Sprues should have either a round cross-section or a rounded trapezoidal construction and must have well-polished surfaces to ensure adequate demoulding.

Normally, a runner diameter with a gated wall thickness " $S + 1.5 \text{ mm}$ " is adequate.

Different flow distances lead to varying curing rates. Usually the result is that cavities with the longest flow distances either cannot fully densify (decreased mechanical and thermal properties, dimensional variations) or cannot be filled completely.

When using multi-cavity moulds, a flow design with equal flow lengths to each cavity should therefore be considered (see figure 2).

Balancing different flow path lengths by modifying sprue diameters should be avoided, if at all possible, since narrower canals are more susceptible to erosion, leading to incorrect flow rates. Also, varying pressures within individual cavities cannot be balanced in this way.

If possible, cavities with different volumes or wall thickness should not be combined within one injection mould.

Gates that are up to today's technical standard for processing thermosets include:

- sprue gate
- pinpoint gate
- fan gate
- tunnel gate

(see figure 3)

Direct injection using a sprue gate should only be used for large parts with a central connection. The disadvantage is the abrupt cutting of the flow front, with unstructured orientation of the fillers, and the extra work required removing the injection slug. In this case, injection compression moulding would be better.

Pinpoint and fan gating require the same constructional considerations as for processing thermoplastics.

Tunnel gates may be used for small parts with wall thickness up to 3 mm.

The injection angle should be about 45° - 50°. With an angle of less than 45°, there is a risk that the sprue will tear off when demoulding and block the gate.

Gate diameter should be 1.0 - 2.5 mm.

The use of a tunnel often is not recommended for flat pieces.

When processing mineral filled products increased wear from abrasion in the gate area may be expected. It is recommended that the gate area of the mould be designed as an insert to allow easy replacement.

### 3.2 Mould Steel

Only those types of steel that are totally unaffected by the temperatures used for processing moulding compounds (normally 150 – 200 °C) should be considered. The most common grades used are 21 Mn Cr 5 (no. 1.2162) and X 19 Ni Cr Mo 4 (no. 1.2764).

A list of the different grades of steel available can be found in table 3.

### 3.3 Mould Tempering

Insulated plates (thickness > 8 mm) between the mould and the machine-supporting base are indispensable in maintaining constant mould temperature. This reduces mould-heating time and prevents excessive stress on machine parts, such as bearings and joints.

Suitable insulation plates made from compression resistant materials with low moisture absorption are available from standard mould manufacturers.

The mould is tempered using electrical resistance heating using either band or cartridge heaters, whereby cartridge heaters have proven best for maintaining high mould temperatures and an even temperature distribution.

Placement of heat cartridges should follow the same guidelines as the placement of cooling channels for thermoplastics to insure an even temperature on the mould surface.

The specific heat output can be calculated using the equation:

$$P = \frac{m \cdot c \cdot T}{t}$$

P = power (W)

m = weight of mould (kg)

c = specific heat of mould steel (kWh/kg.K)

T = temperature difference (K)

t = pre-heating time (h)

(recommended: P = approx. 20 W/kg steel)

When specific heat output is too high, the required load is also high and the mould may become either overheated or damaged from jamming.

Too low a specific heat output means that either the required temperature is not reached or the heating time is too long. A heating time of 60 minutes should be considered.

Control thermocouples should be placed near the cavities, but not too close to the heating elements.

The electronic temperature regulators should be able to control the zone temperatures constantly within  $\pm 2^\circ \text{C}$  where required (moulding precise parts, fast curing compounds, etc.) and should not be worse than  $\pm 5^\circ \text{C}$ . They should also be regularly controlled to ensure that the temperature readings are correct.

### 3.4 Demoulding Angles

An adequate number of core ejectors is required to ensure an easy demoulding from each cavity. For flat cavities, A demoulding angle of  $0.5^\circ$  is sufficient; For cases and long cores, a increased angle of  $1 - 2^\circ$  can be used, provided the part's dimensional tolerances allow.

The ejectors should be self-cleaning and polished in the direction of demoulding to avoid unnecessary force.

### 3.5 Degassing

The importance of degassing cannot be stressed enough, especially since inadequate degassing causes many defects in the finished parts. The air in the mould must be displaced during the injection phase and the gaseous products formed during the curing phase (mostly water) must also be able to escape.

Degassing can be aided by the ejectors (by cutting small vents along the edges), again emphasising their proper placement.

Vents should be placed at the end of the flow paths and where flow fronts meet so that the gases may easily escape from the cavities and should be constructed (polished, chrome plated, ejector) to ensure adequate demoulding of the flash. In multi-cavity moulds, flash sticking will ultimately result in inadequate filling of individual cavities.

Vents should be 0.02 - 0.05 mm deep and about 3 - 5 mm wide, depending on the product and the flow ratio.

### 3.6 Demoulding-inclination (Draft)

All planes (areas) of the part that are in the direction of demoulding must have a demoulding-inclination (draft). The following values are recommended:

PF, MF, MPF : 1 - 2°

UP : 2 - 3°

In well-designed moulds, lower drafts can be used without any problem.

### 3.7 Further Design Guidelines

For details, please see figures 4 & 5.

#### Corners and rounded edges

Sharp leading edges should be avoided due to the high demoulding rigidity of thermo-setting compounds. Instead, rounded edges  $\geq 0.5$  mm or, where possible,  $\geq 2$  mm curvatures should be considered. The material flows easier into the mould, reducing cavity-filling problems, and, coupled with the demoulding inclination, the ejection process is made easier.

#### Stiffening and Ribs

Rib constructions  $< 0,8$  mm should be avoided due to the risk of breakage. On the other hand, too thick a construction may lead to surface finish problems or to indentations.

Flow problems may also occur if they are not optimally positioned.

#### Back drafts

Back drafts should be avoided. Where structural penetration is necessary, demoulding becomes difficult. Mould slides or after-baking become necessary resulting in complicated and fault-susceptible moulds, thereby increasing costs.

#### Flash to Margin

The margins of the mould should be constructed so that breakages during demoulding or flash removal are avoided. Guidelines can be found in figure 5.

#### Relief Designs

Holes and penetrations are formed by the moulding compound coating cones or pins in the mould. There is a danger that these could break if they are positioned too close to the margins. Therefore there should be sufficient room from the margin or a slit leading to the edge.

Breakages will also occur if the wall thickness of any holes is insufficient.

### 3.8 Mould coatings

Mechanically resistant coatings are recommended when processing thermosetting compounds for the following reasons:

- increased resistance to abrasion from fillers (inorganics, glass fibres)
- reduction of surface finish impurities from flash adherence.
- less sticking, resulting in easier demoulding
- increased corrosion resistance to the by-products of curing.

The oldest type of coating is galvanised hard chrome plating, which can have a hardness of 800 – 1100 HV with thickness between 30 and 50 µm and bath temperatures between 55 and 60 °C.

Recent developments in coating are Physical Vapour Deposition (PVD), Chemical Vapour Deposition (CVD) and Plasma Chemical Vapour Deposition (Plasma CVD).

In the PVD process, the coating is vaporised at 200 – 500 °C and directly applied to the mould.

The CVD process is similar to that of PVD except that the coating is chemically fixed to the mould after application. A disadvantage of this process is that higher temperatures are required (500 – 1100 °C), which could damage the mould.

Plasma CVD, on the other hand, is suitable for temperature-sensitive moulds, since the process is carried out at temperatures < 300 °C. The coating is applied either by electrical discharge in the thermal plasma or using cold plasma at reduced pressure.

CrN-coating has proven to be one of the best mechanically resistant materials for processing various thermosetting compounds. However, the final choice of coating should be made after consulting the mould constructors.

## **II. PRESS PROCESSING**

Although; in principle, all free-flowing thermosetting moulding compounds are suitable for press processing, better results are obtained using those compounds that have been developed, with respect to their flow-curing behaviour, for this procedure.

Dosage can be carried out by weight or by volume, i.e. the material can be processed directly, as tablets (with or without pre-heating) or can be preplastified prior to use.

The temperature and pressure within the closed mould forces the softened material into the cavities. After the required curing time, which is dependent on the wall thickness of the processed part, mould temperature and the reactivity and pre-treatment of the moulding material, the finished part is removed from the mould. Depending on the part size, This process can be carried out manually, semi-automatically or automatically.

Press processing is used to produce parts with low filler orientation and low shrinkage.

Press moulds nowadays normally are constructed with a bleed out. These guarantee the precise production of finished parts due to ideal compaction.

The factors concerning mould design and mould steel are the same as for injection processing.

The parameters for press processing of our moulding compounds can be found in table 2.

September 2003 / Raschig GmbH, R&D, Dr. Hennersdorf/J. A. Campbell

**Table 1: Guidelines for Injection Moulding of Thermosetting Moulding Compounds**

| Moulding Compound                     | RESINOL   | RALUPOL      | MELOPAS      | AMPAL        |
|---------------------------------------|---|--------------|--------------|--------------|
| Cylinder temperatures                 |   |              |              |              |
| Loader                                | Room temp.  | Room temp.   | Room temp.   | Room temp.   |
| Zone 1 (screw zone)                   | 60 – 80 °C  | 50 – 70 °C   | 70 – 90 °C   | 50 – 75 °C   |
| Zone 2 (Nozzle zone)                  | 80 – 100 °C   | 80 – 100 °C  | 90 – 100 °C  | 80 – 100 °C  |
| Compound temperature leaving nozzle   | 105 – 115 °C  | 100 – 115 °C | 100 – 115 °C | 100 – 115 °C |
| Screw speed                           | 70 – 100 rpm  | 70 – 100 rpm | 80 – 120 rpm | 80 – 120 rpm |
| Backing up pressure                   | 5 – 15 bar  | 10 – 15 bar  | 8 – 12 bar   | 8 – 12 bar   |
| Dwell pressure wrt injection pressure | 50 – 70 %   | 60 – 80 %    | 60 – 80 %    | 80 – 100 %   |
| Dwell pressure time                   | 2 – 8 s   | 10 – 20 s    | 10 – 15 s    | 10 – 20 s    |
| Mould temperature                     | 165 – 185 °C  | 165 – 185 °C | 165 – 185 °C | 165 – 185 °C |
| Curing time *)                        | 10 – 100 s  | 10 – 100 s   | 10 – 100 s   | 10 – 100 s   |
| Remarks                               | After injection time and dwell pressure time, the injection unit should be drawn back |              |              |              |

\*) not usually dependent on wall thickness

**Table 2: Guidelines for Pressing of Thermosetting Moulding Compounds**

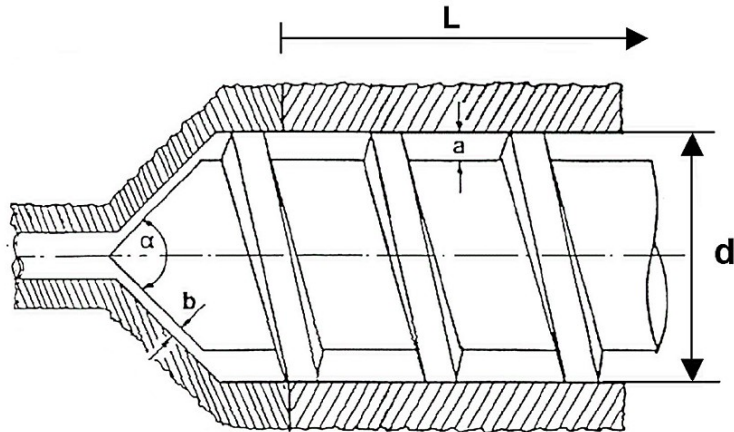
| Moulding compound                               | RESINOL      | RALUPOL      | MELOPAS      | AMPAL        |
|---|--------------|--------------|--------------|--------------|
| Mould temperature                               | 165 – 180 °C | 165 – 180 °C | 160 – 180 °C | 160 – 180 °C |
| Internal pressure                               | min. 200 bar | min. 100 bar | min. 200 bar | min. 100 bar |
| Curing time pro mm wall thickness <sup>1)</sup> | 20 – 50 s    | 10 – 35 s    | 20 – 50 s    | 20 – 50 s    |

<sup>1)</sup> curing times dependent on pre-treatment (pre-heating; pre-plastification) of the moulding compound.

These values are meant only as guidelines. Adaptations may be necessary, depending on the type of machine and/or mould.

**Table 3: Selection of Common Steels for Mould Construction**

| Type no. | DIN Designation | Composition (%) |      |      |       |      |      |      |      | Remarks   | Applications  |
|----------|-----------------|-----------------|------|------|-------|------|------|------|------|---|---|
|          |                 | C               | Si   | Mn   | Cr    | Mo   | Ni   | V    | S    |   |   |
| 1.2162   | 21 MnCr5        | 0,21            | 0,25 | 1,25 | 1,20  |      |      |      |      | Resistant to abrasion; easily polished and machined, can be embossed and/or plated.                 | Mirror finishes   |
| 1.2764   | X 19NiCrMo4     | 0,19            | 0,25 | 0,40 | 1,25  | 0,20 | 4,00 |      |      | Strong; easily polished and machined, can be embossed and/or plated.                                | Complicated or highly stressed moulds                         |
| 1.2767   | X 45NiCrMo4     | 0,45            | 0,25 | 0,40 | 1,35  | 0,25 | 4,00 |      |      | Very strong; easily polished; reduced distortion; can be photoetched; erodable and nitrable.        | Profile or sections   |
| 1.2083   | X 42Cr13        | 0,42            | 0,40 | 0,30 | 13,00 |      |      |      |      | Abrasion and corrosion resistant; very easily polished; high dimensional stability during tempering | Profile or sections   |
| 1.2379   | X 155CrVMo121   | 1,55            | 0,30 | 0,30 | 12,00 | 0,70 |      | 1,00 |      | good tempering properties; resistant to abrasion; good strength; nitrable; not easily polished      | Screws, injection moulding and pressing moulds, closing rails |
| 1.2311   | 40 CrMnMo7      | 0,40            | 0,30 | 1,50 | 1,90  | 0,20 |      |      |      | Strong; can be polished; can be embossed or eroded; nitrable; good dimensional stability            | Mould steel, moulds with structured surfaces                  |
| 1.2312   | 40 CrMnMoS86    | 0,40            | 0,40 | 1,50 | 1,90  | 0,20 |      |      | 0,06 | rapid machining; strong; can be polished; cannot be embossed or plated; good dimensional stability  | Mould frames  |
| 1.2343   | X 38CrMoV51     | 0,38            | 1,00 | 0,40 | 5,30  | 1,20 |      | 0,40 |      | good tempering properties; high resistance to abrasion; nitrable and easily polished                | Screws, Moulds  |
| 1.1730   | C45W3           | 0,45            | 0,30 | 0,70 |       |      |      |      |      | uncoated mould steel with good strength and machinability   | Mould frames, mountings                                       |



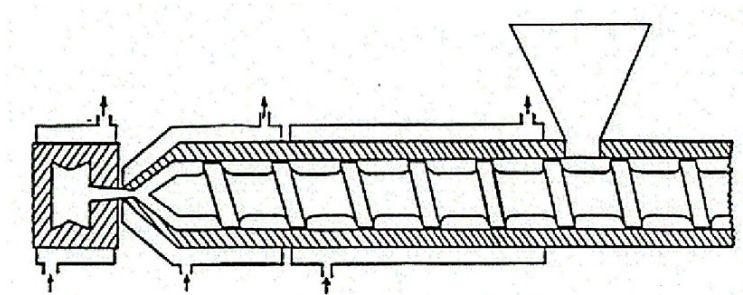
**Plastification screw**

Screw tip angle  $\alpha = 75 - 90^\circ$

Screw channel depth  $a = 3.0 \text{ mm}$  (for  $d = 20 \text{ mm}$ )

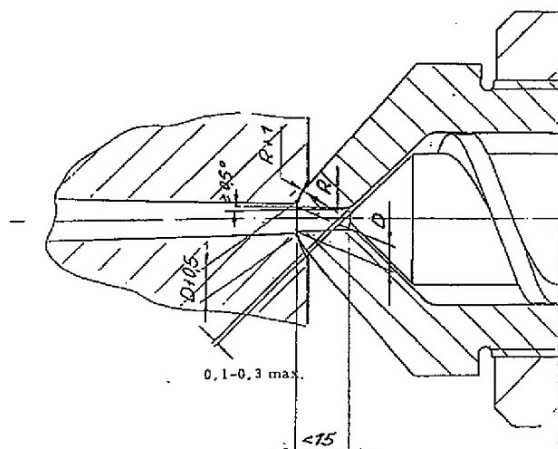
Ratio  $L/d = 1:15 - 19$

Gap  $b$  (max.) =  $0.4 \text{ mm}$



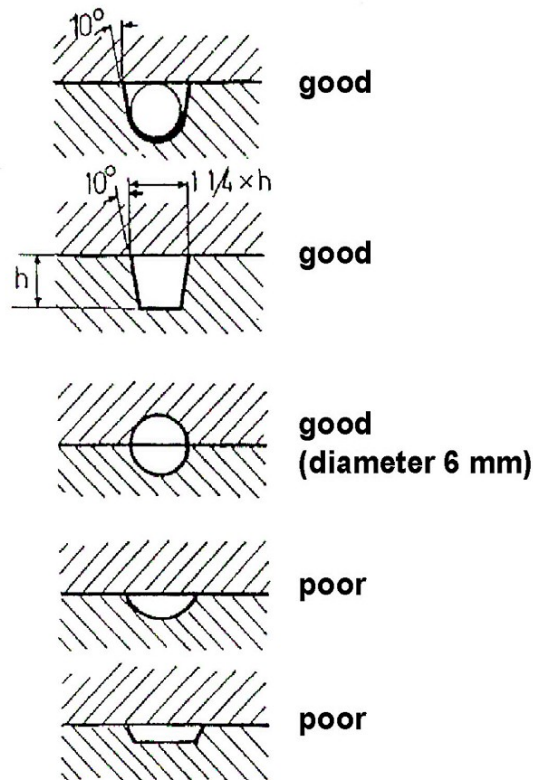
**Injection unit**

minimum of two separately regulated heating zones

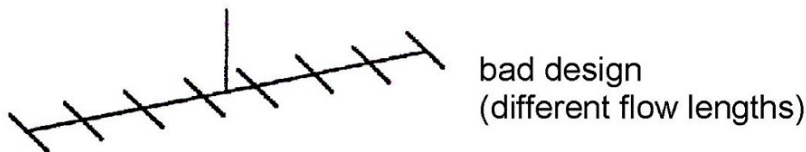


**Nozzle**

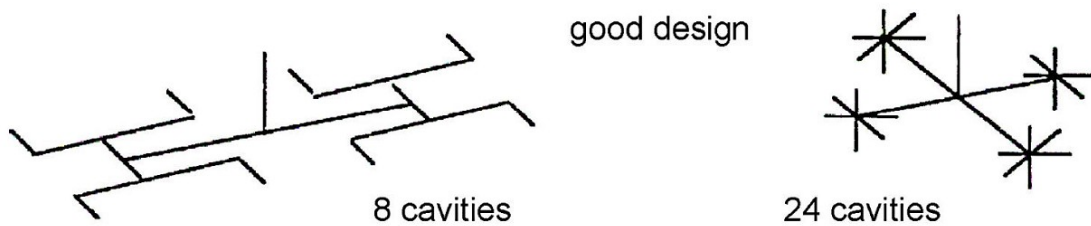
**Figure 1: Injection Moulding Machines for Thermosetting Compounds**



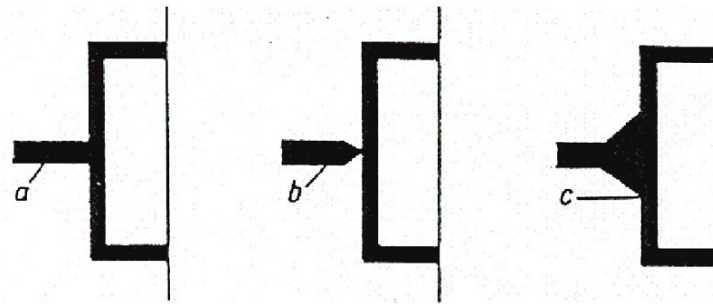
**Runner construction**



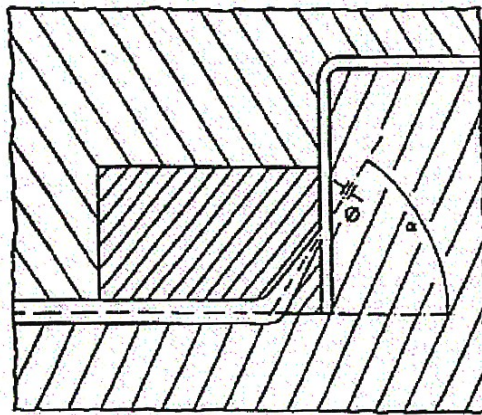
**Runner systems for multi-cavity moulds**



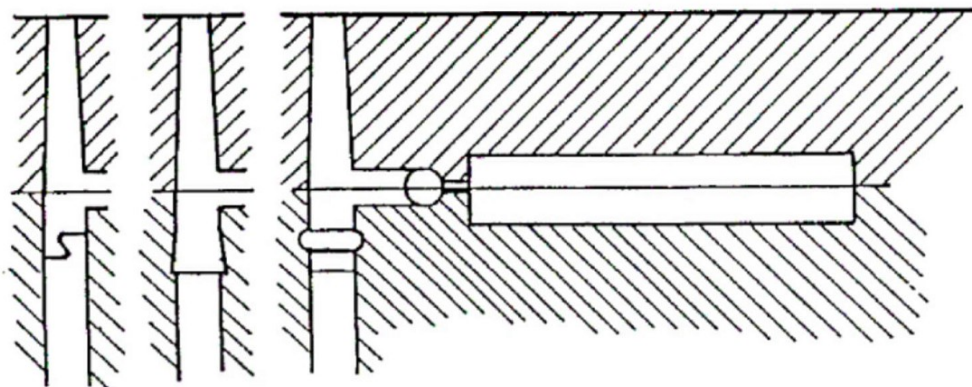
**Figure 2: Runner systems**



a = Sprue gate    b = Pinpoint gate    c = Fan gate



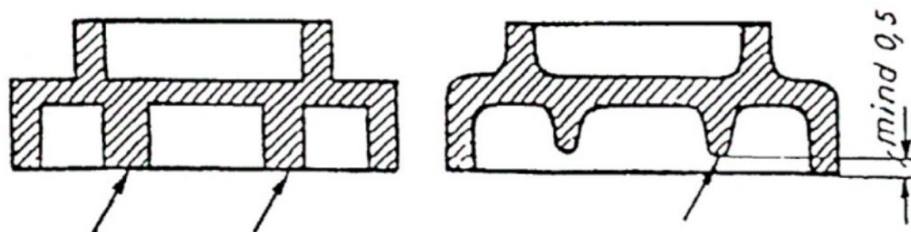
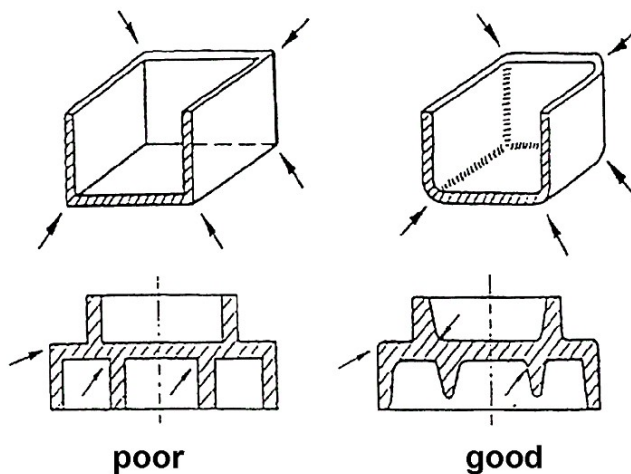
Tunnel gate:  $\varnothing = 1.0 - 2.5 \text{ mm}$   
 $\alpha = 45 - 55^\circ$



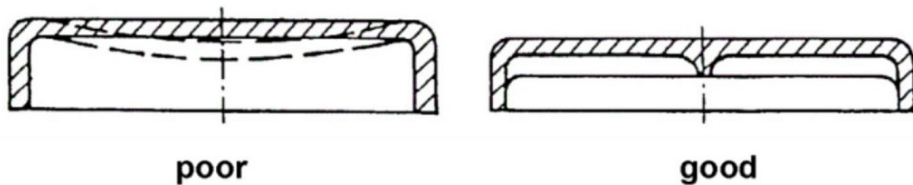
Sprue lock

Figure 3: Gates and Sprue lock

rounded corners



stiffening



back draft

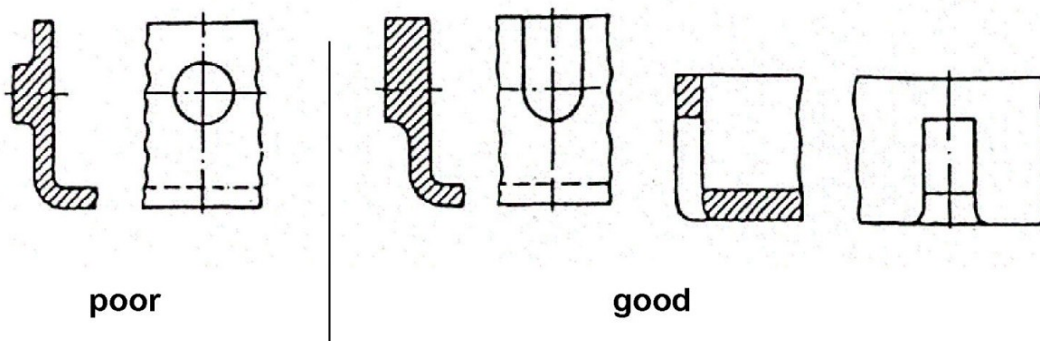
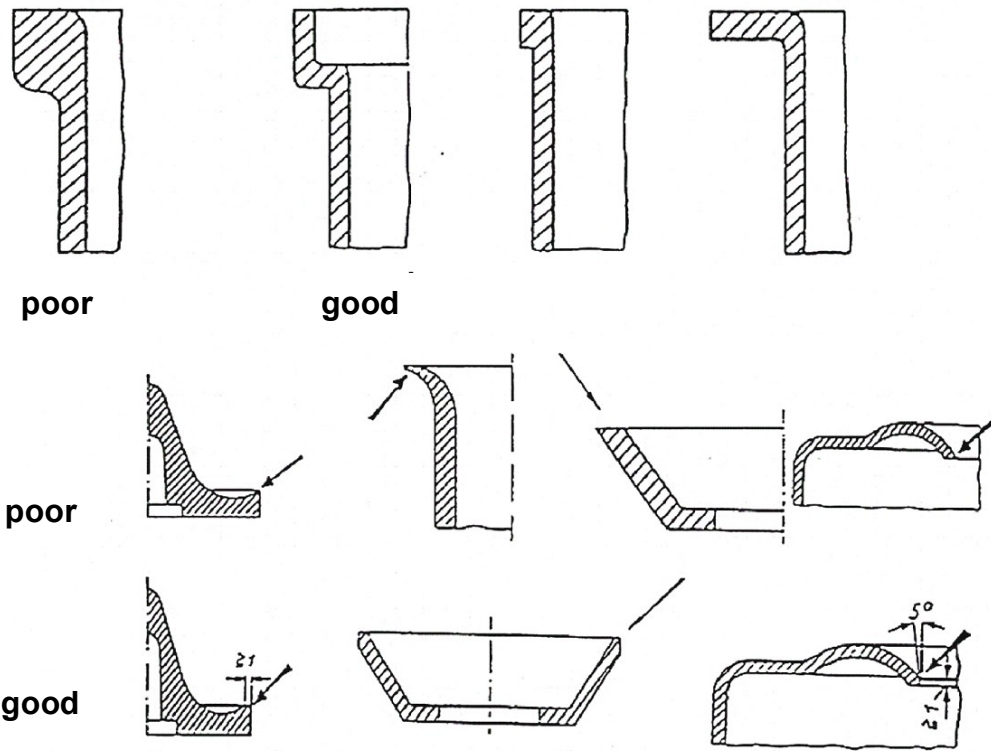
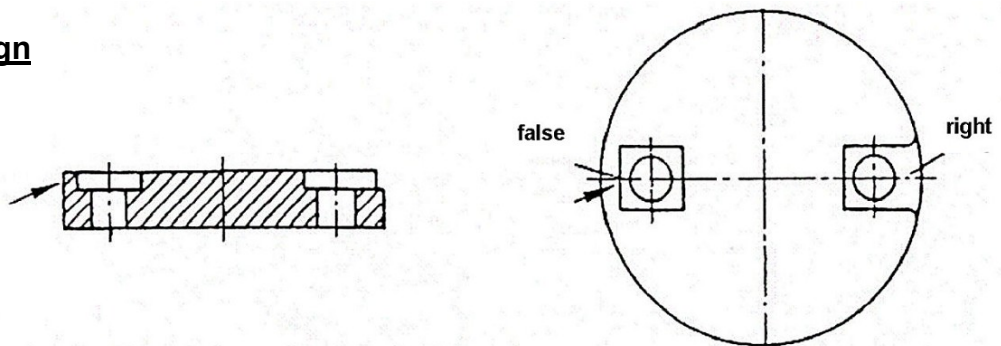


Figure 4: Mould design - 1



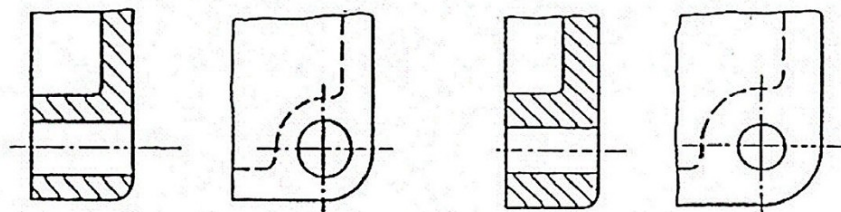
**Flash to margin!**

**Relief design**



Left side: poor  
Right side: good

Left side: poor  
Right side: good



**poor**

**good**

**Forming of breakthrough and hole**

**Figure 5: Mould Design - 2**