New Ideas. New Materials.

UNIVERSITÄT DES SAARLANDES

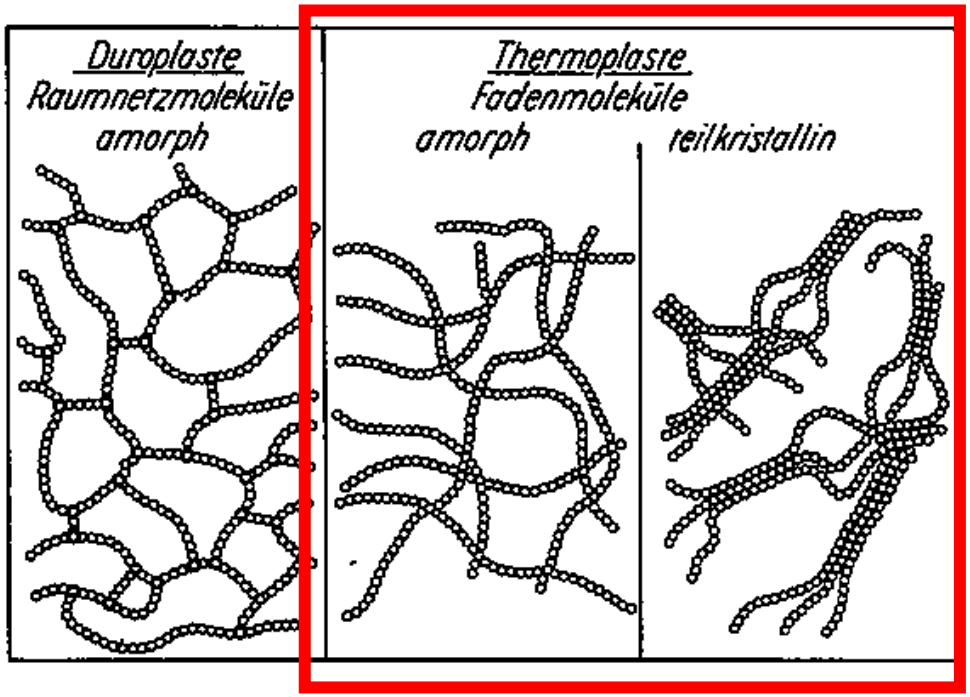
INM

# TECHNOLOGIE POLYMERE & KOMPOSITE

MC07, UdS WS 2019/2020

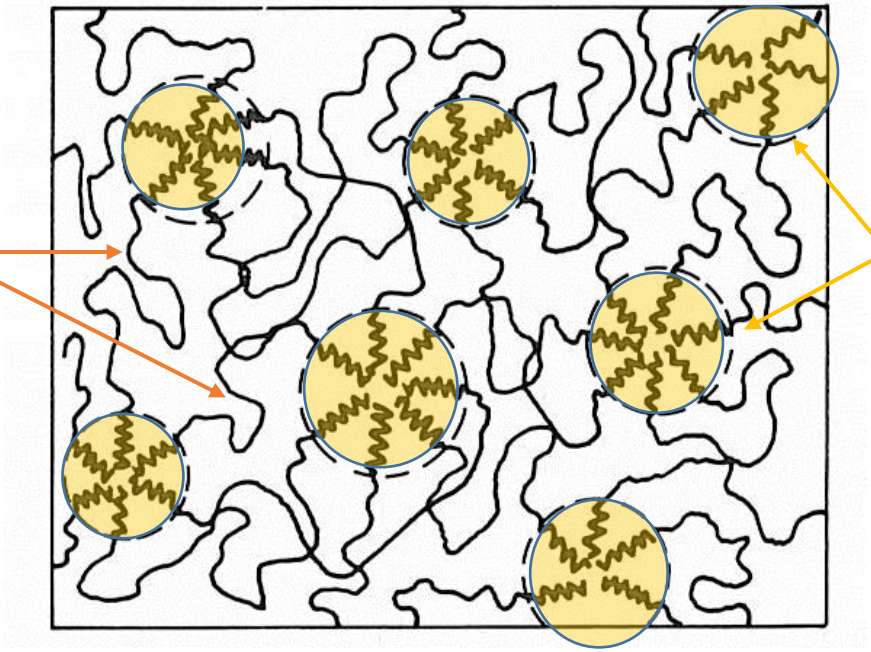
Chapter 7: Melt mixing and Extrusion

# Thermoplastic processability



# Thermoplastic elastomers

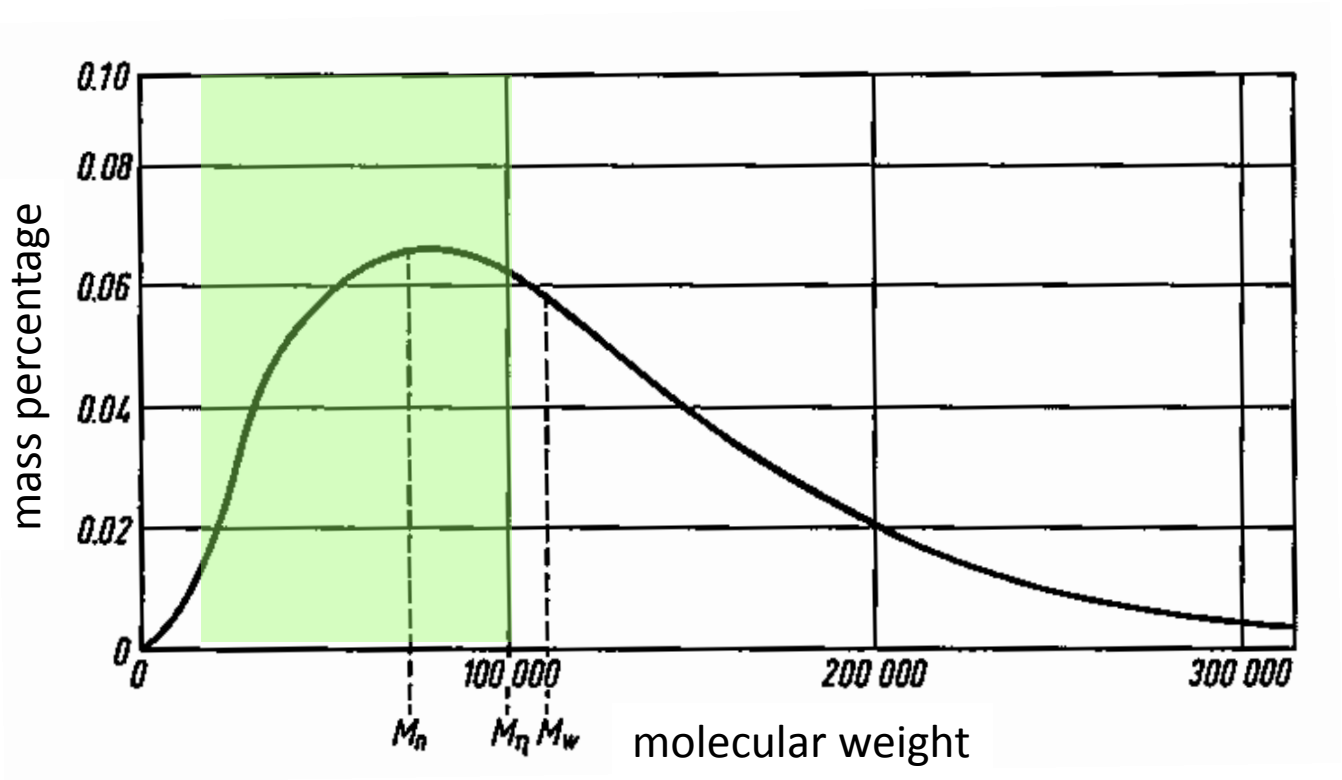
example of elastoplastic copolymer



rubber-like chains

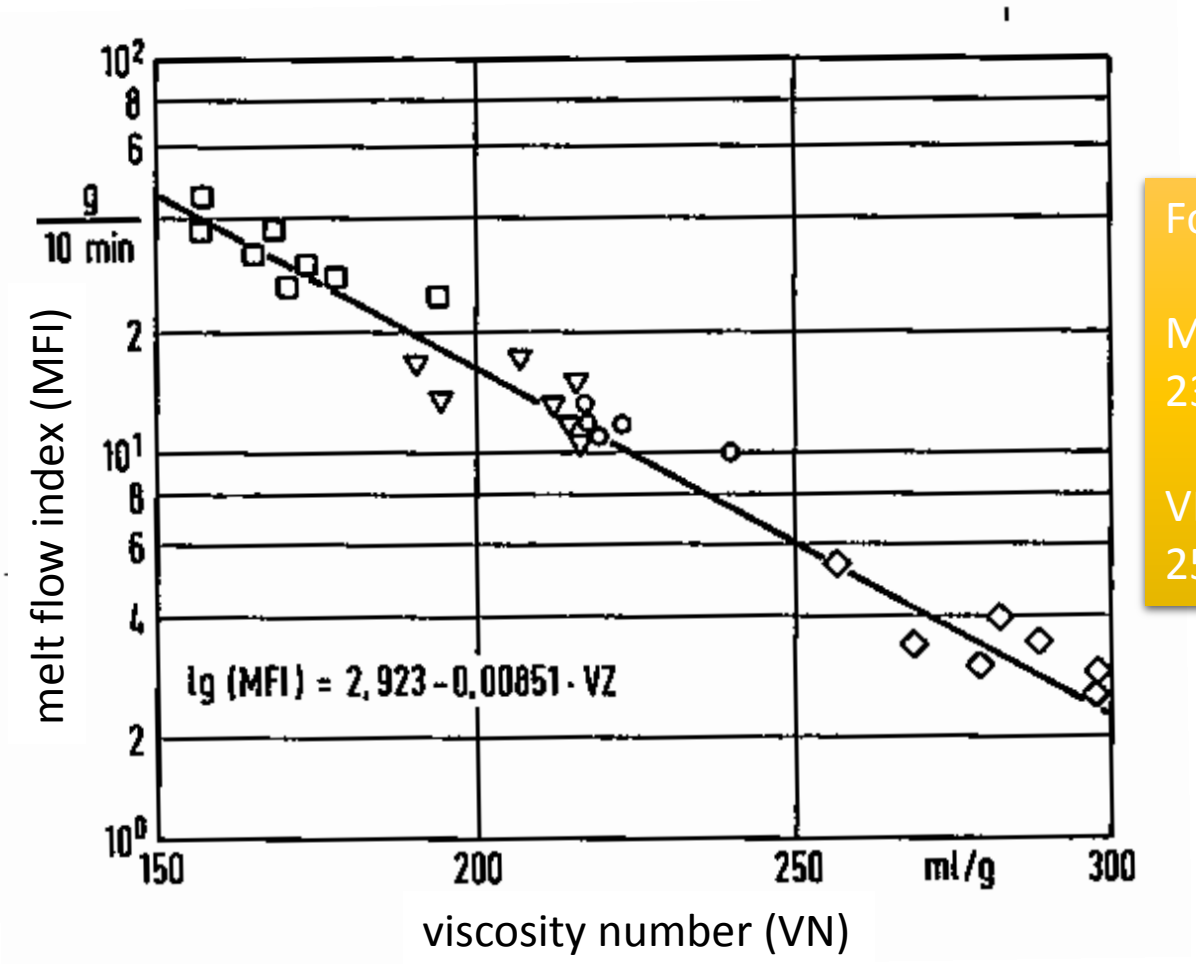
aggregates of glassy chains

# Molecular weight and flow behaviour in molten state




M = $10^4$…$10^5$ g/mole most influence on flow behaviour, $T_g$ and $T_m$

# Relation between viscosity and melt flow index



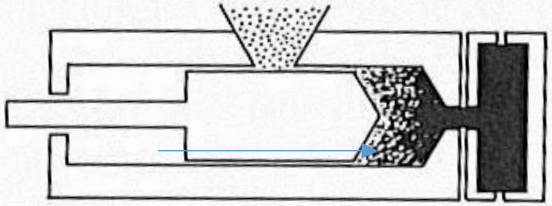

For example PA-6:

MFI at
235°C, 2.16 kg

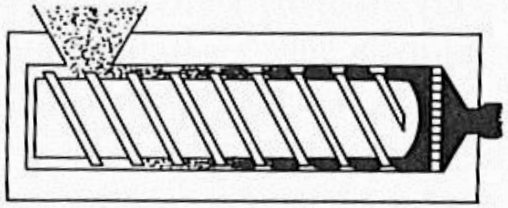
VN at
25°C, m-Kresol 10 g/l

# Injection moulding and extrusion

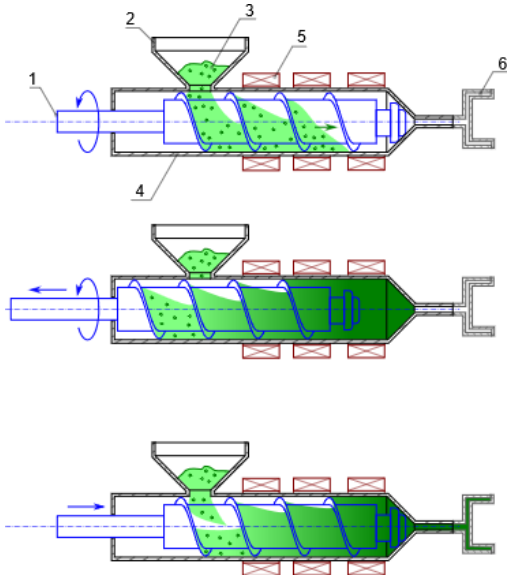
injection moulding



extrusion



with torpedo

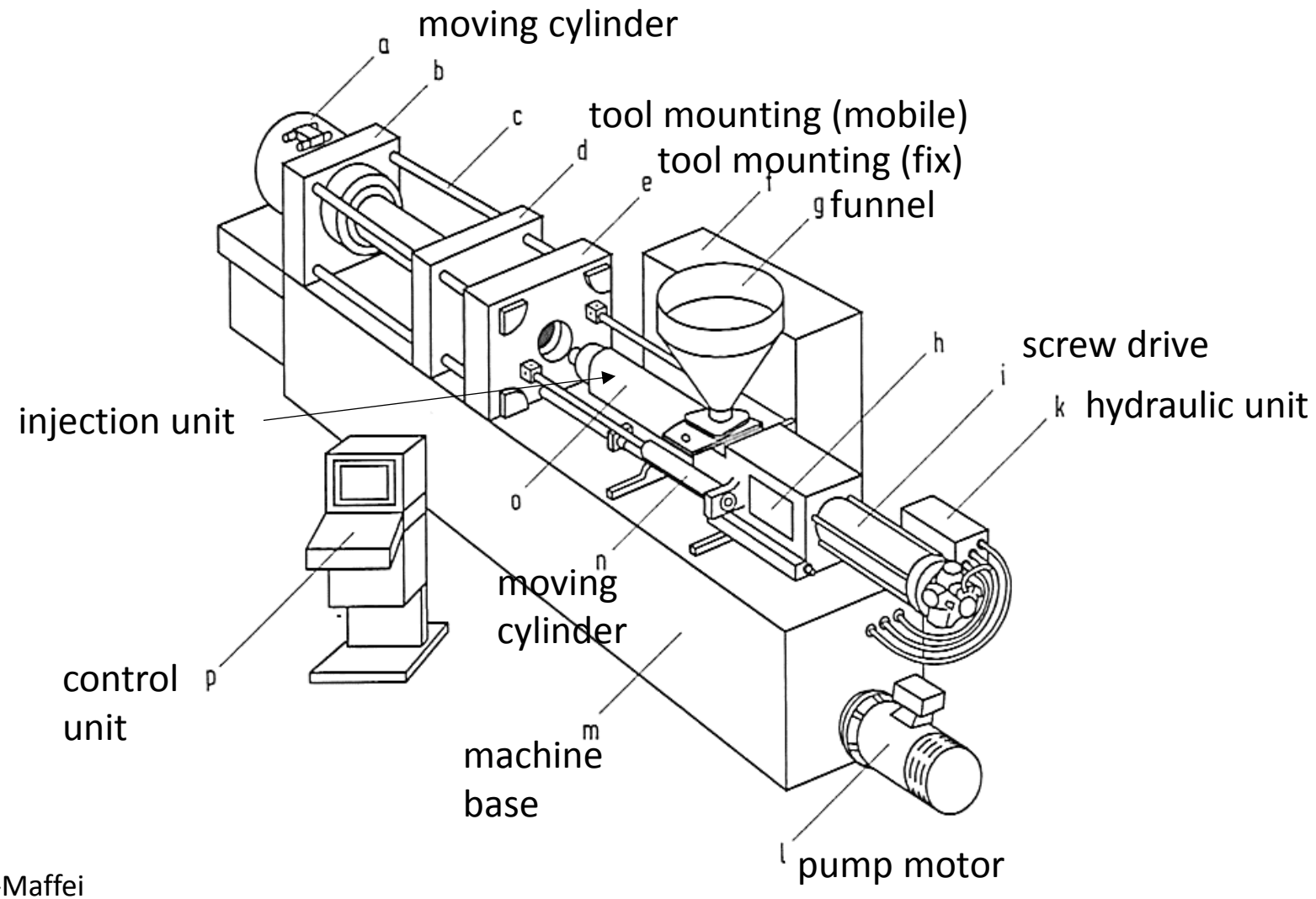



- original mould process
- plastified material
- temperature
- mould with cavity
- pressure
- step-wise process

with single screw

- plastified material
- high shear forces
- mixing process
- temperature
- continuous production
- no pressure after nozzle

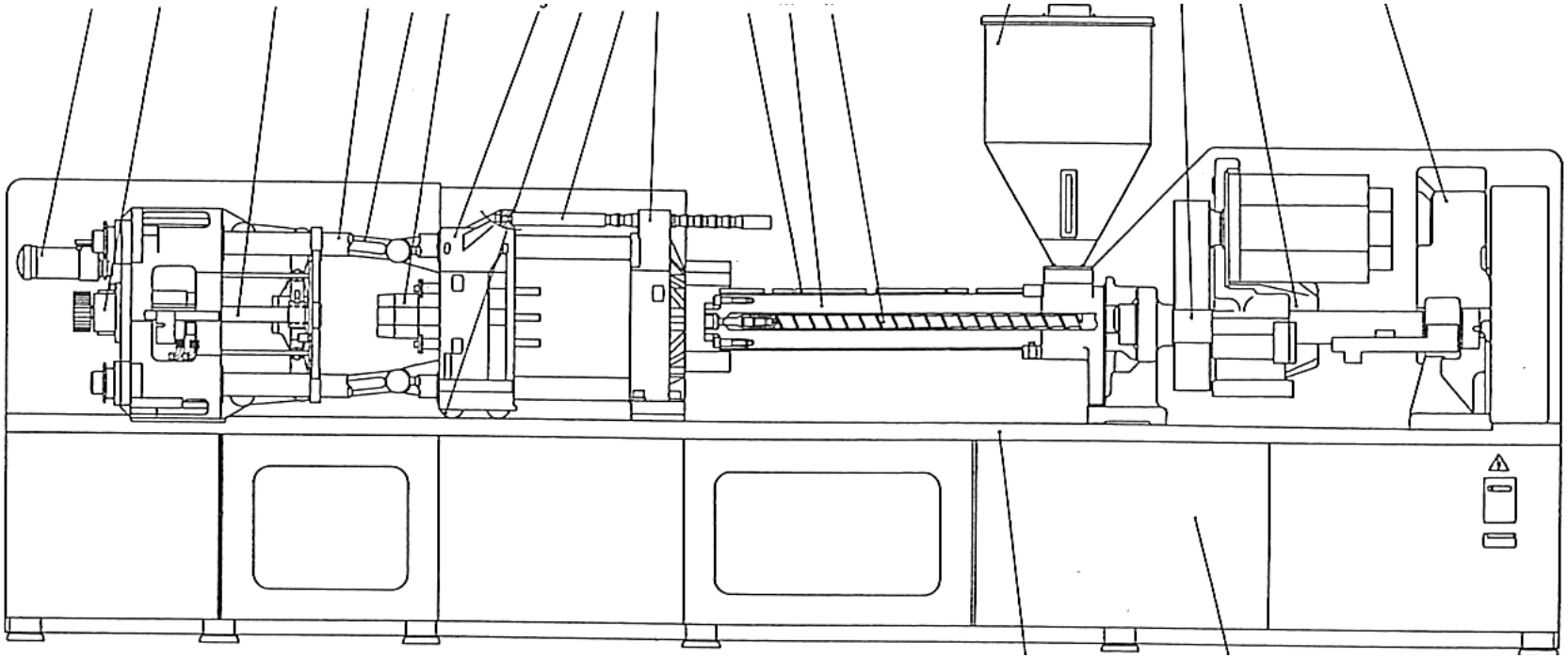
# Injection moulding machine (hydraulic)




Krauss-Maffei

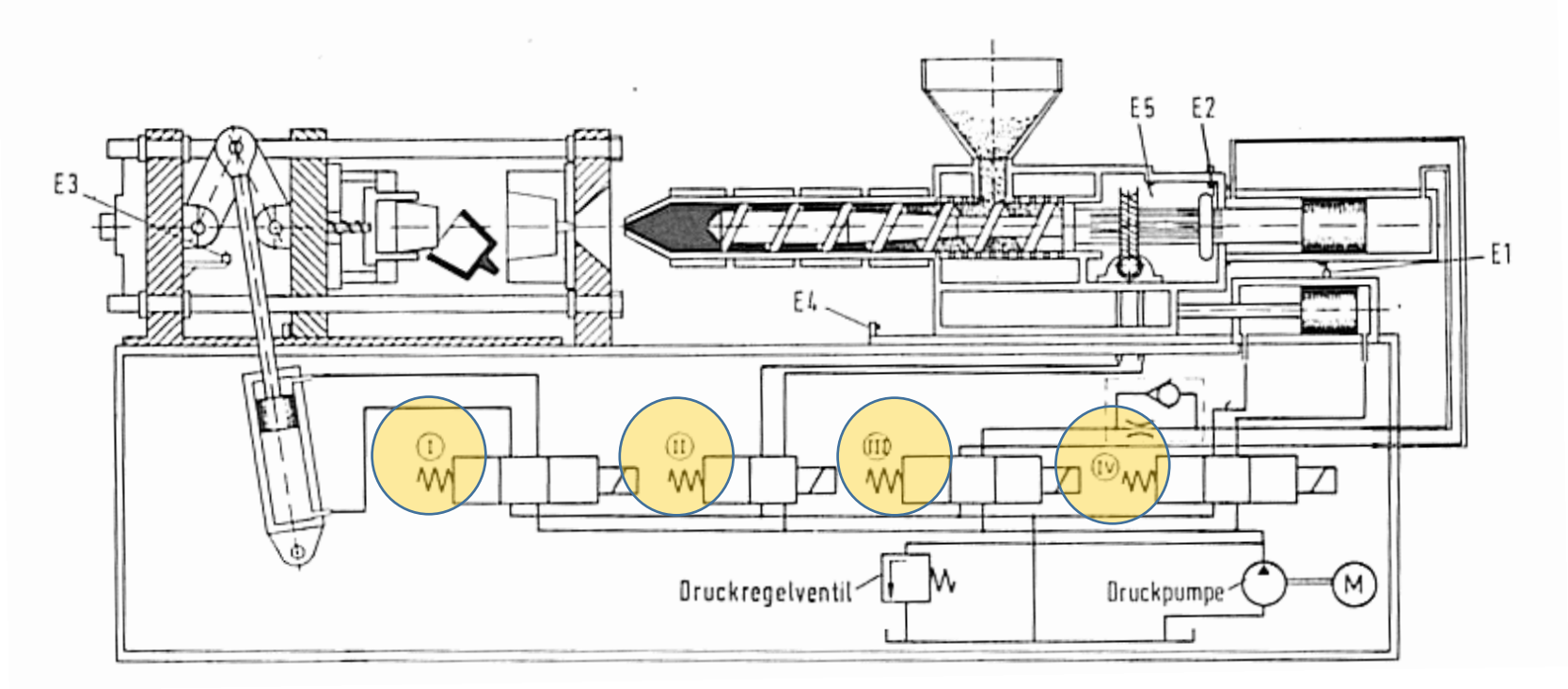
# Injection moulding machine

# Injection moulding machine (all-electric)



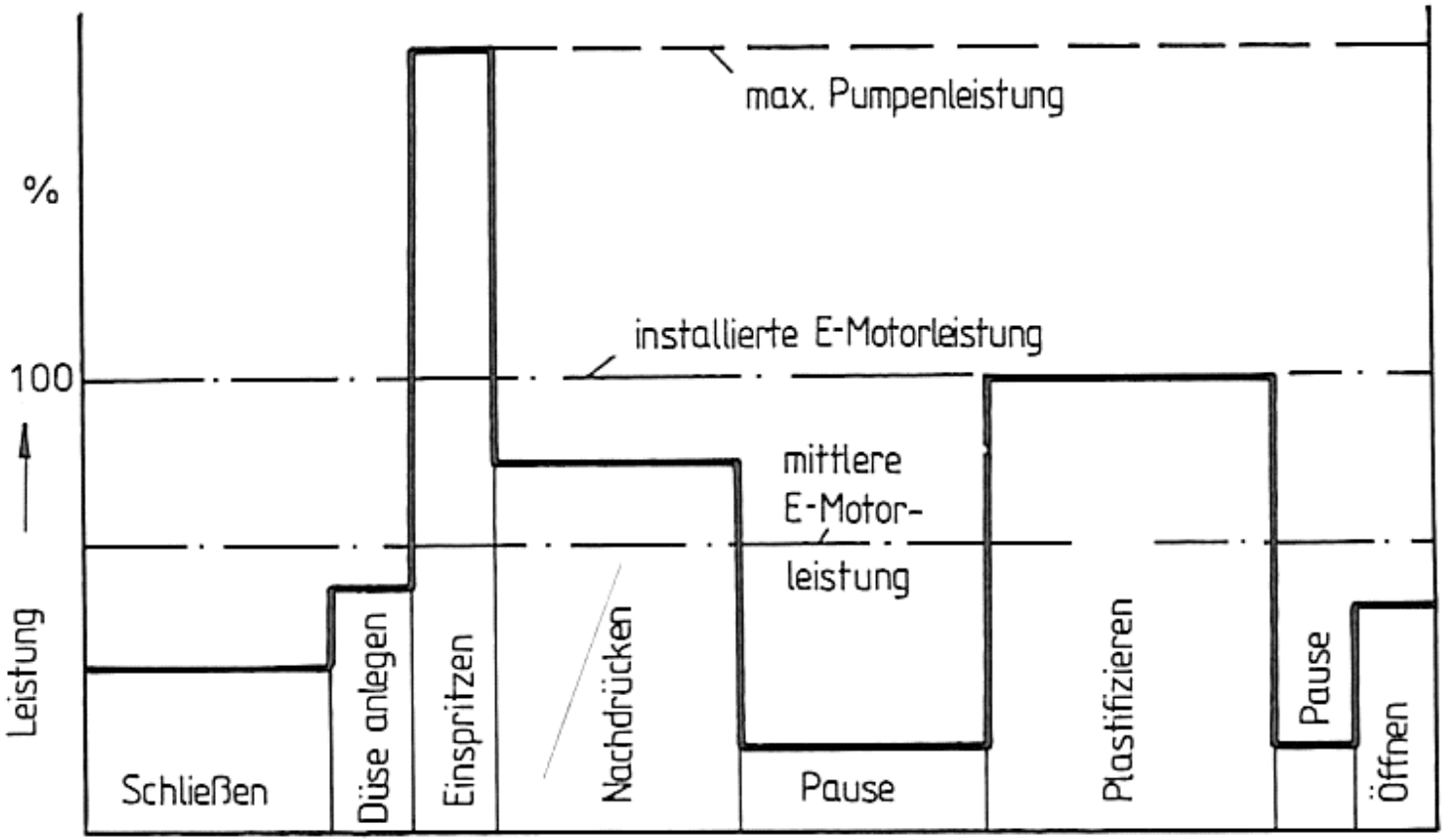
Cincinnati Milacron

# Controlling and timing of hydraulic injection moulding m.



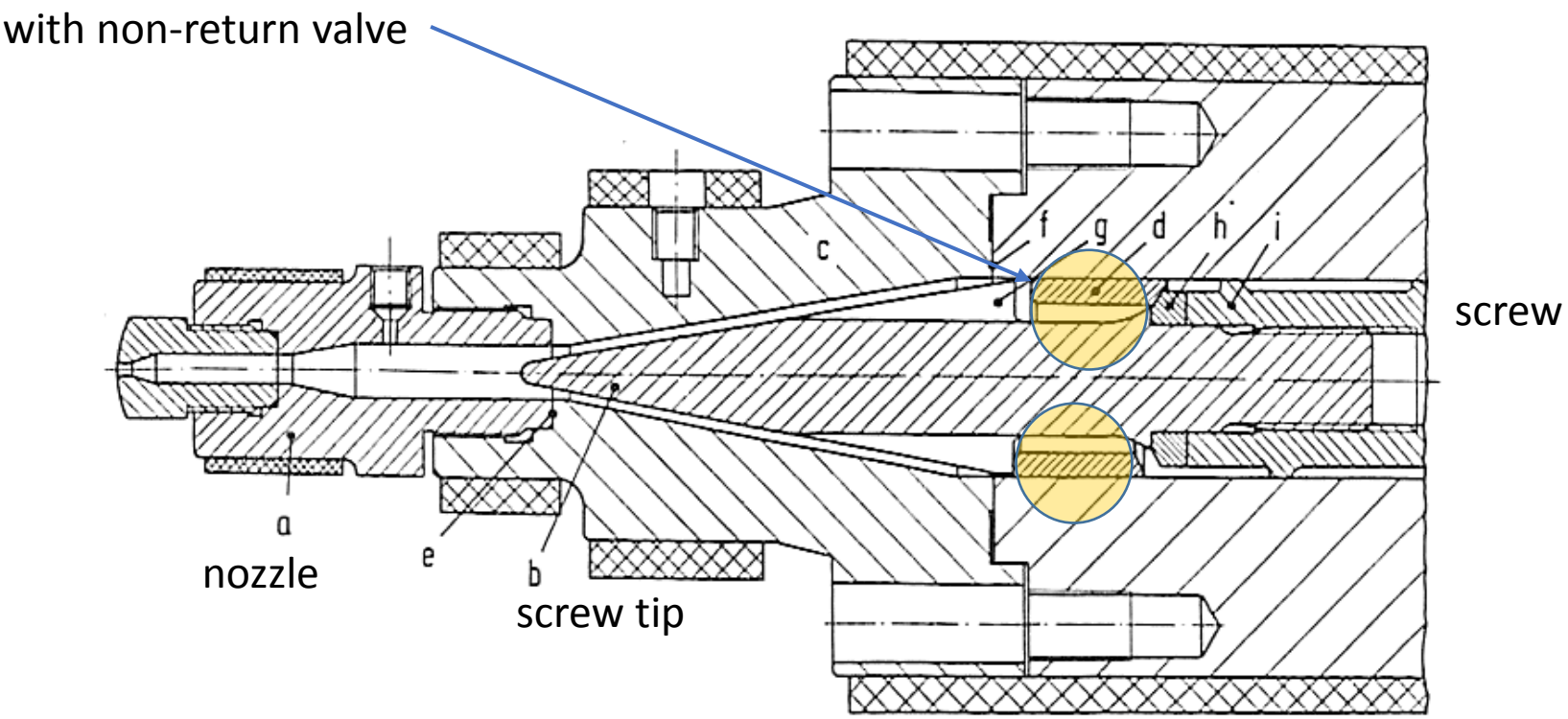

I: closing of tool
II: dosing by rotating and reverse moving screw
III: injection and post-pressure
IV: injection unit back and forward

# Power drain of injection moulding machine

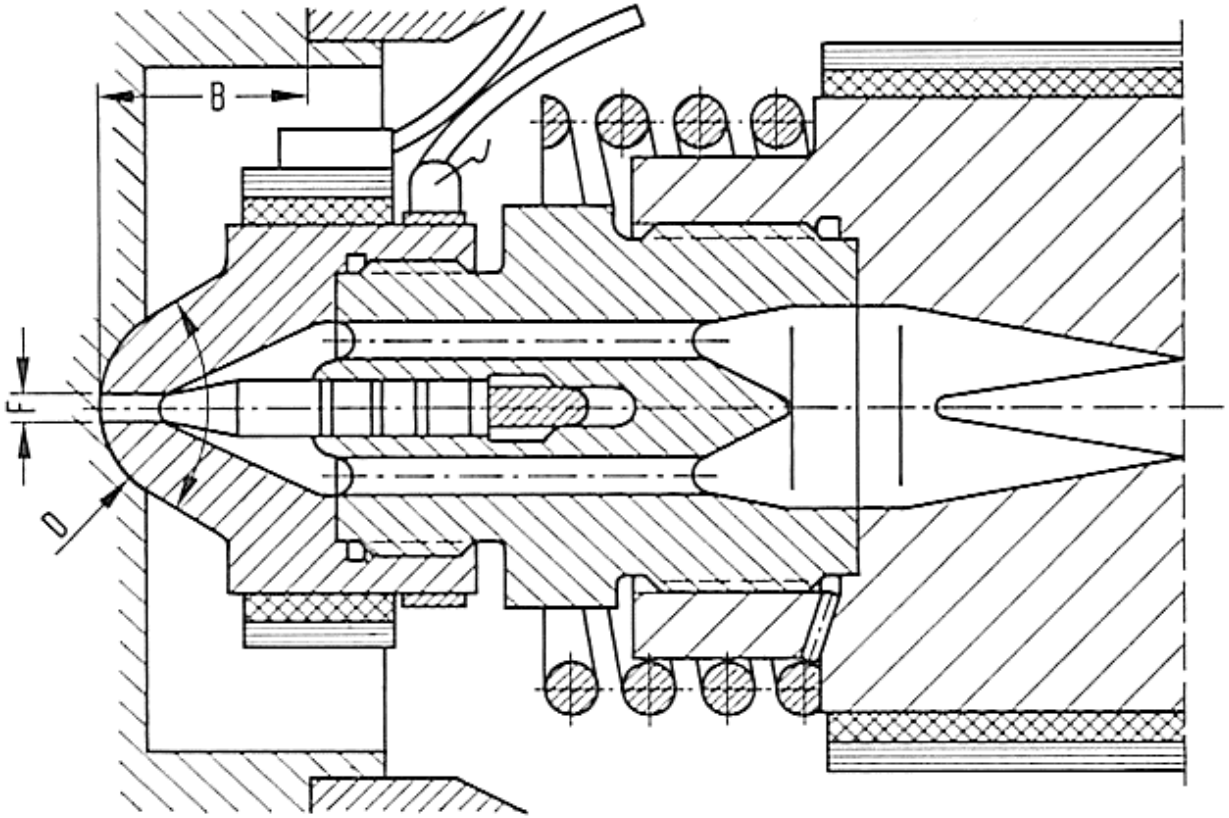



Leistungsaufnahme einer Spritzgießmaschine während eines typischen Zyklus im Vergleich zur installierten E-Motorleistung und zur maximalen Pumpenleistung bei Überlastung des E-Motors

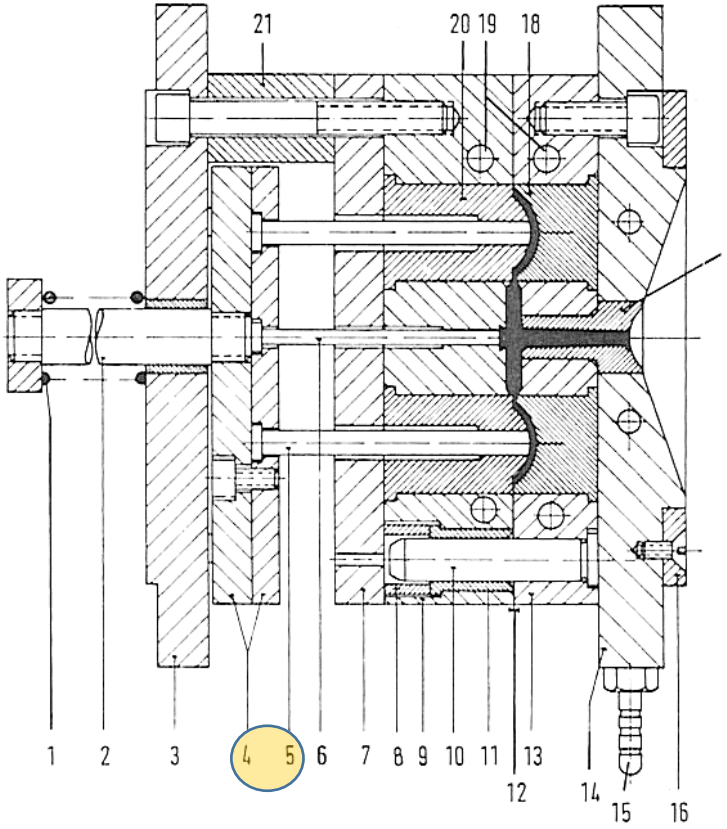
# Construction principle of screw tip



# Needle valve nozzle with spring

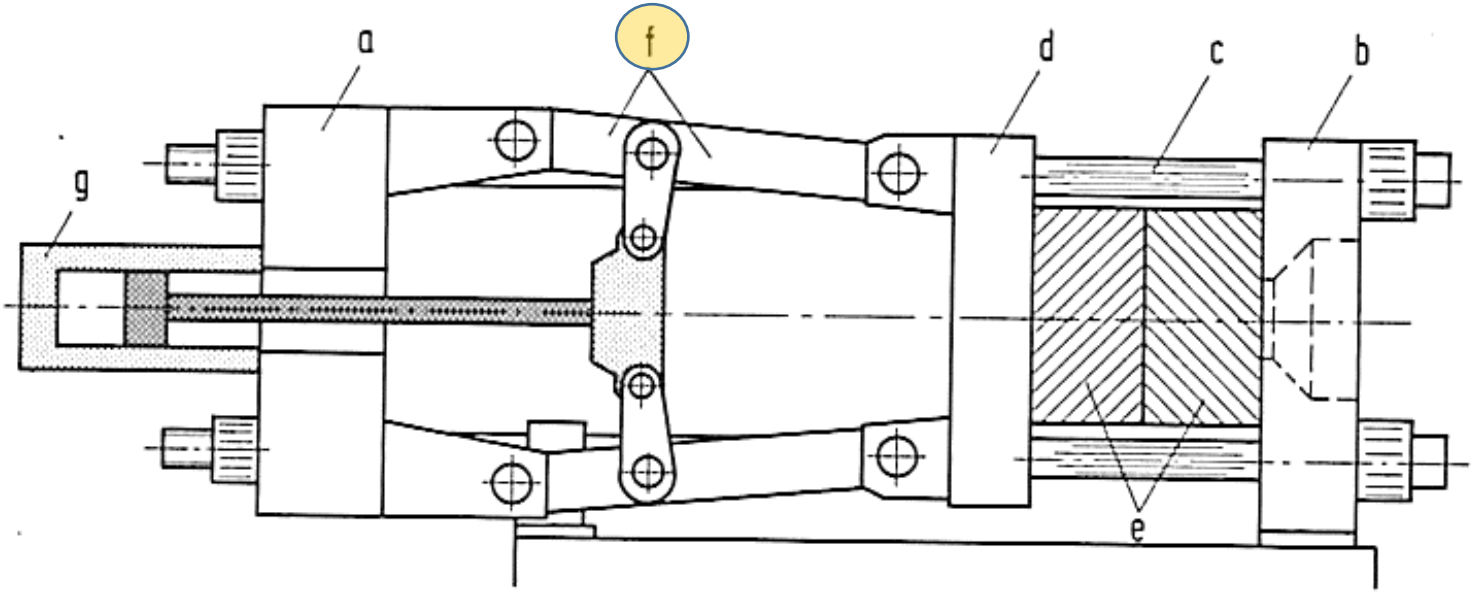


# Denominations of injection moulding tools

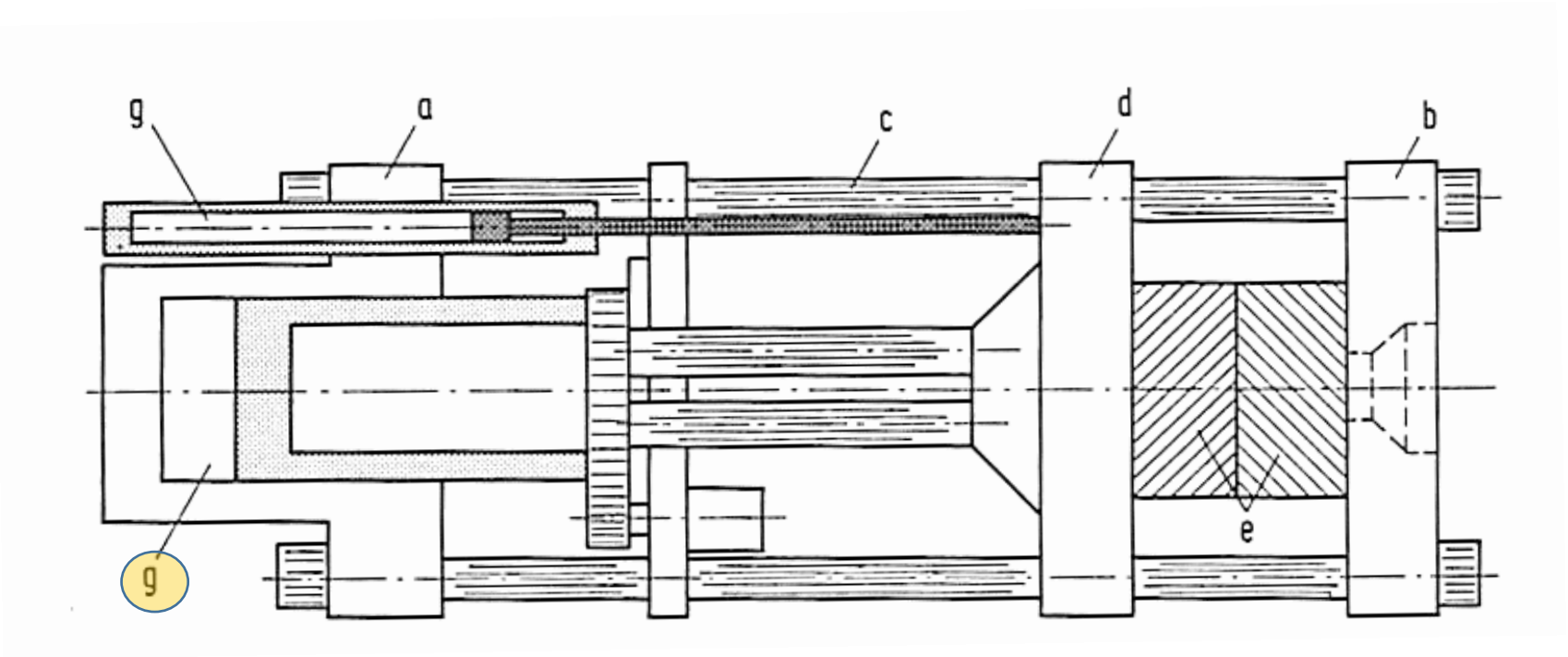



1 - Druckfeder
2 - Auswerferstößel
3 - schließseitige Aufspannplatte
4 - Auswerferplatte
5 - Auswerfer
6 - Mittenauswerfer
7 - Zwischenplatte
8 - Zwischenbuchse
9 - Formplatte
10 - Führungssäule
11 - Führungsbuchse
12 - Formtrennebene
13 - Formplatte
14 - spritzseitige Aufspannplatte
15 - Schlauchnippel für Anschluß der Kühlung
16 - Zentrierring
17 - Angußbuchse
18 - Formeinsatz
19 - Kühlbohrung
20 - Formeinsatz
21 - Stützbuchse

# Closing unit for mould with knee lift

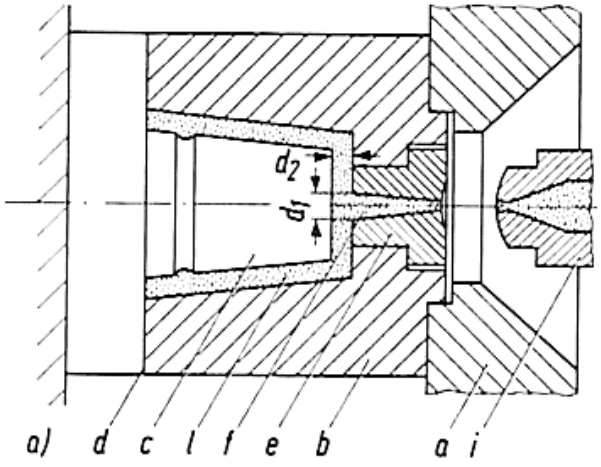


# Closing unit for mould with hydraulic cylinder

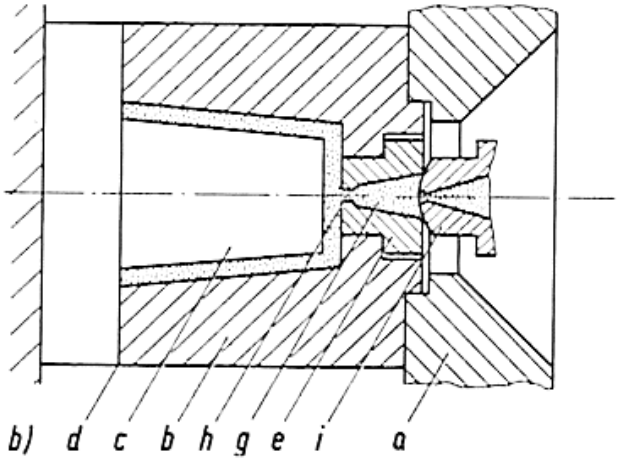


# Center feed for beaker shaped parts

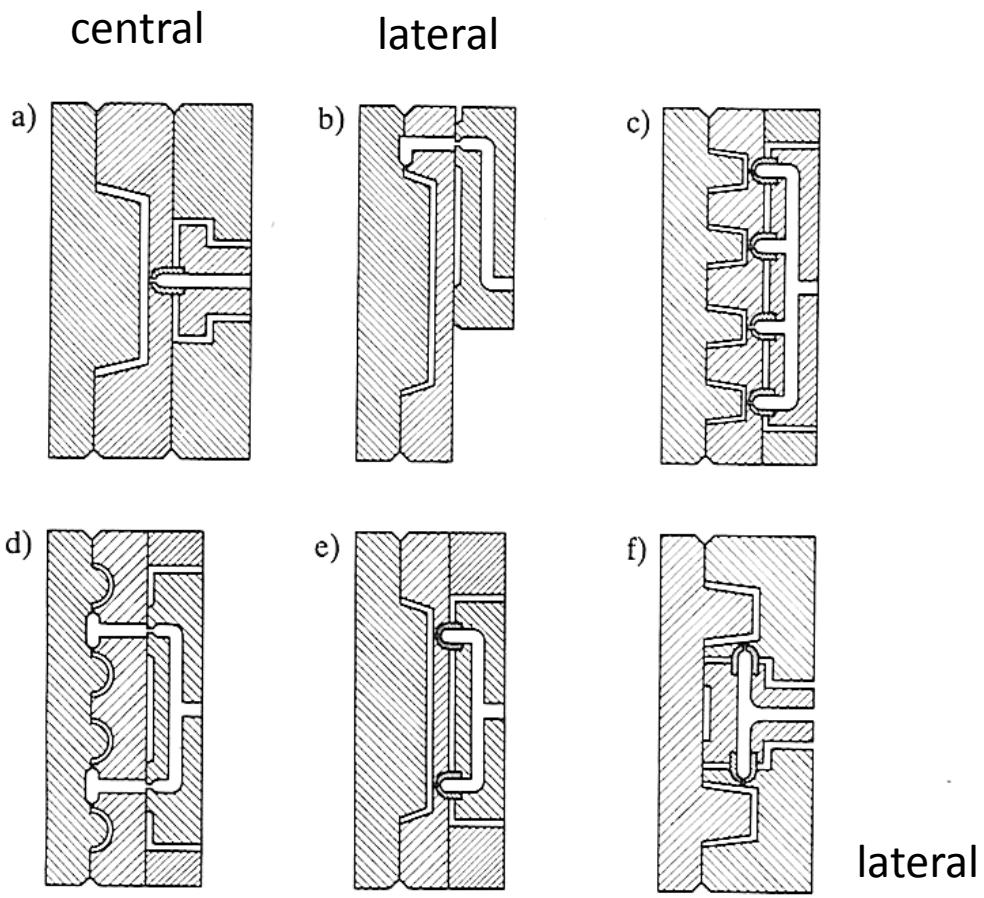
cone type feed




point type feed with prechamber



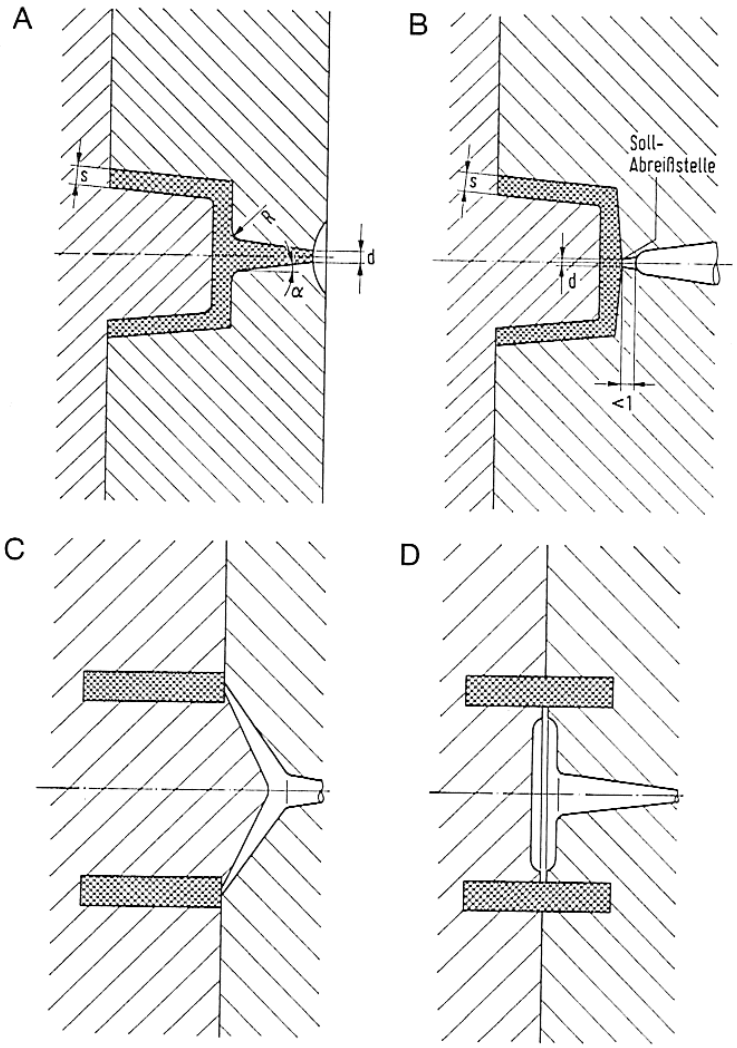
# Different designs for mould feeds and channels



# Some injection moulds from the inside

# Different feed designs

bar type



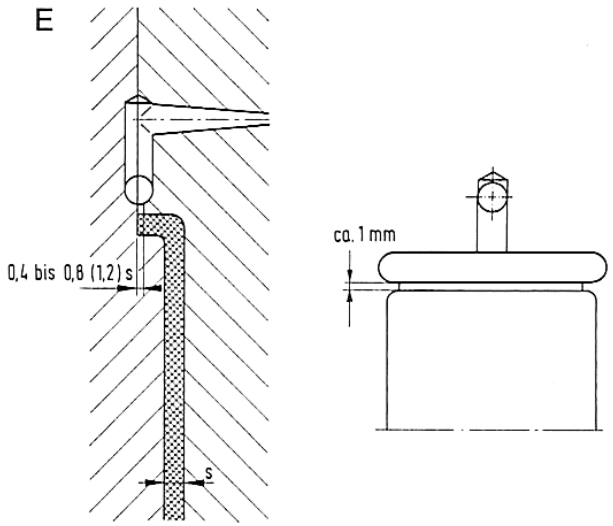

point type

umbrella type

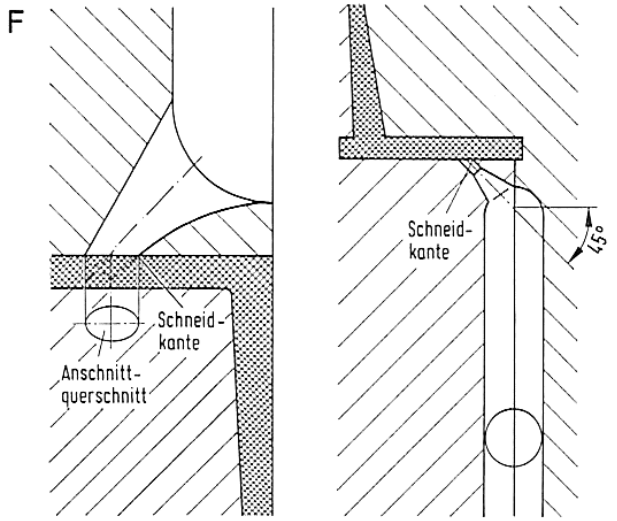
disc type

# Different feeding gate design

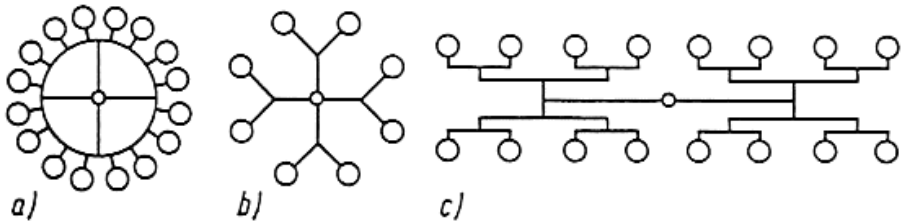
band



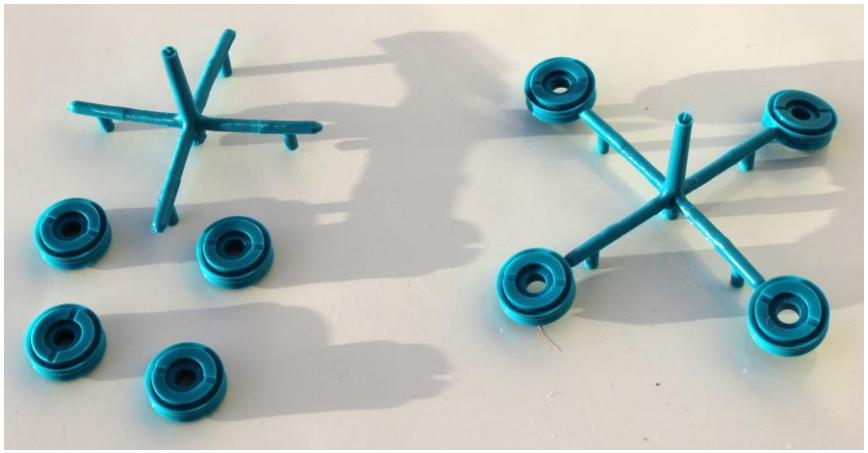

tunnel



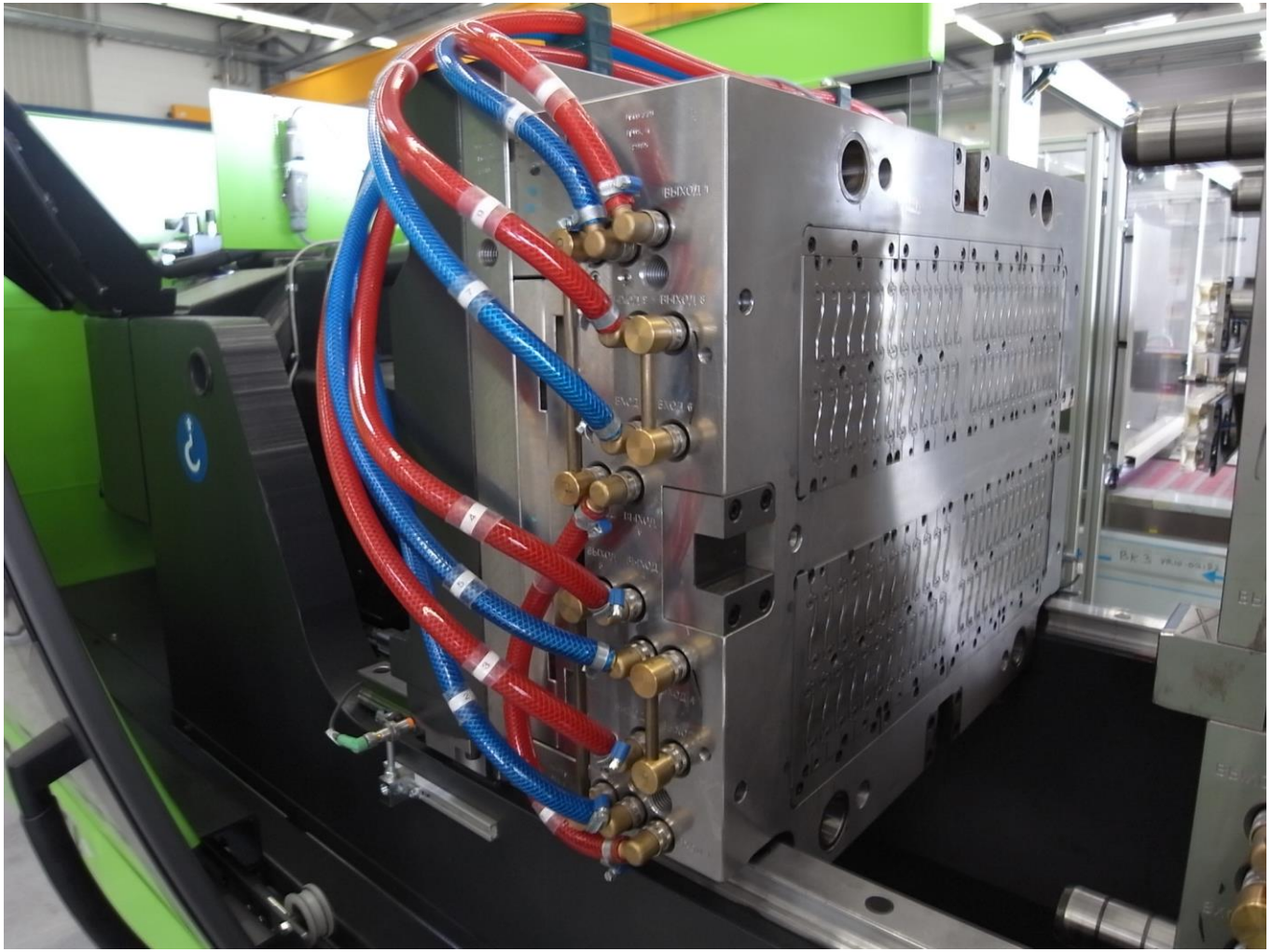
# Multi part tools / moulds



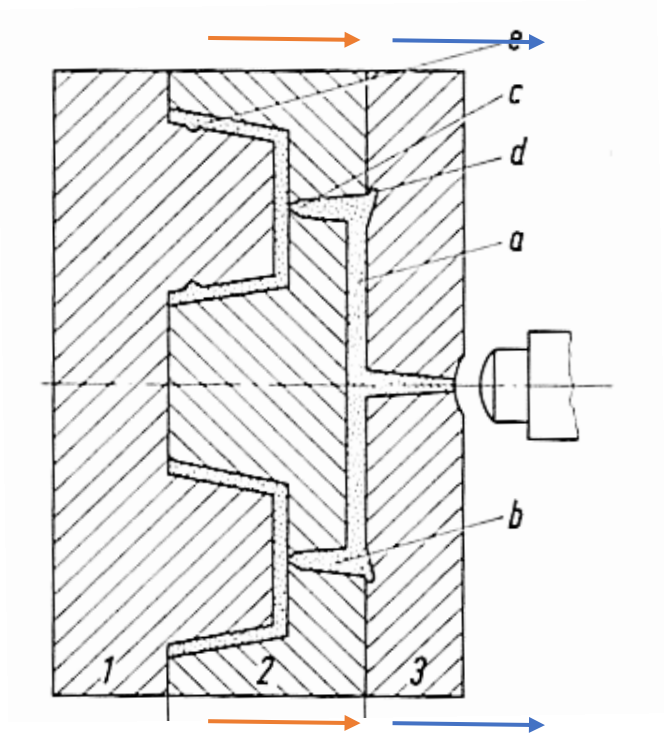

! c) different flow pathway length



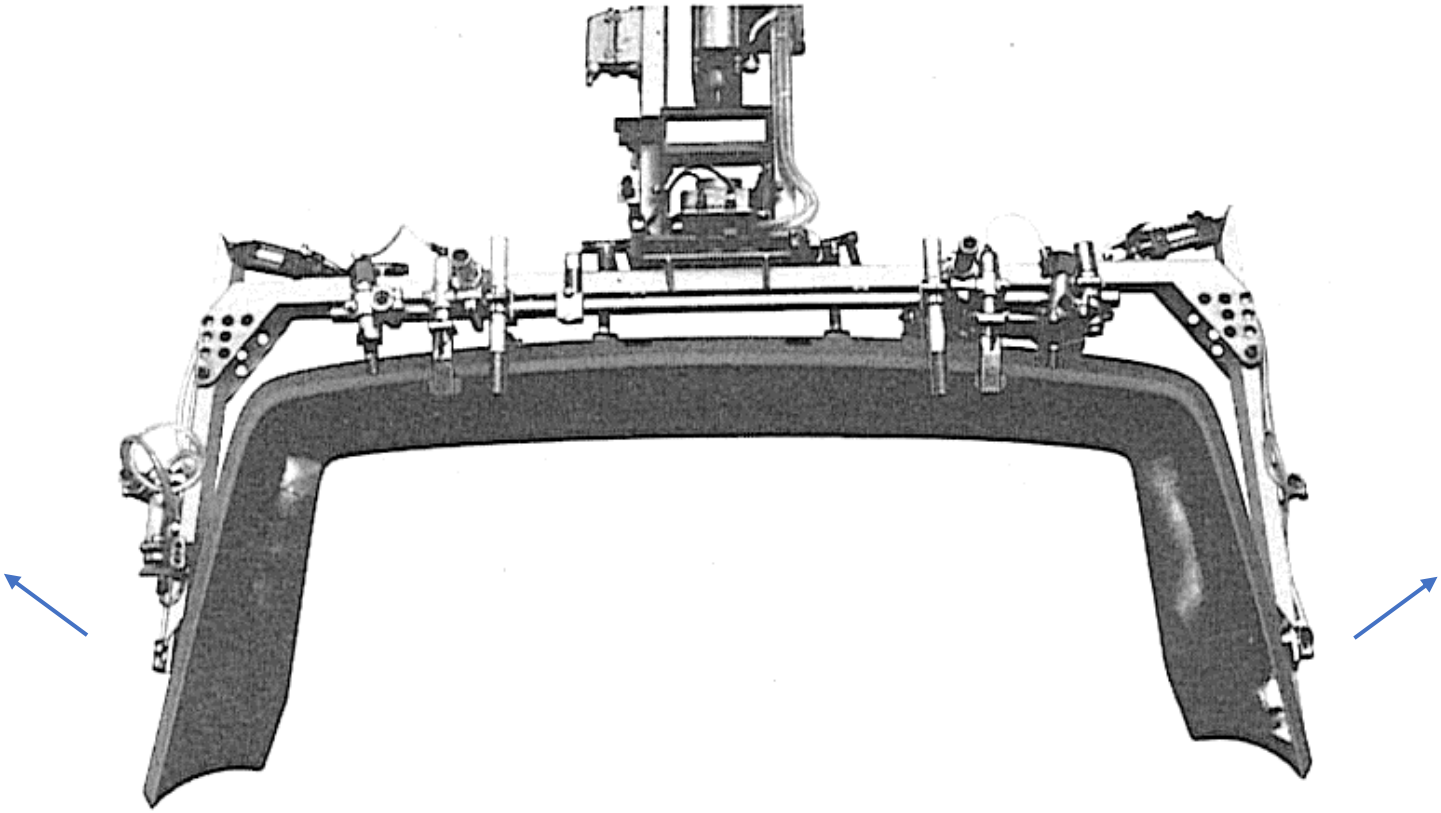
# Typical multi part tool



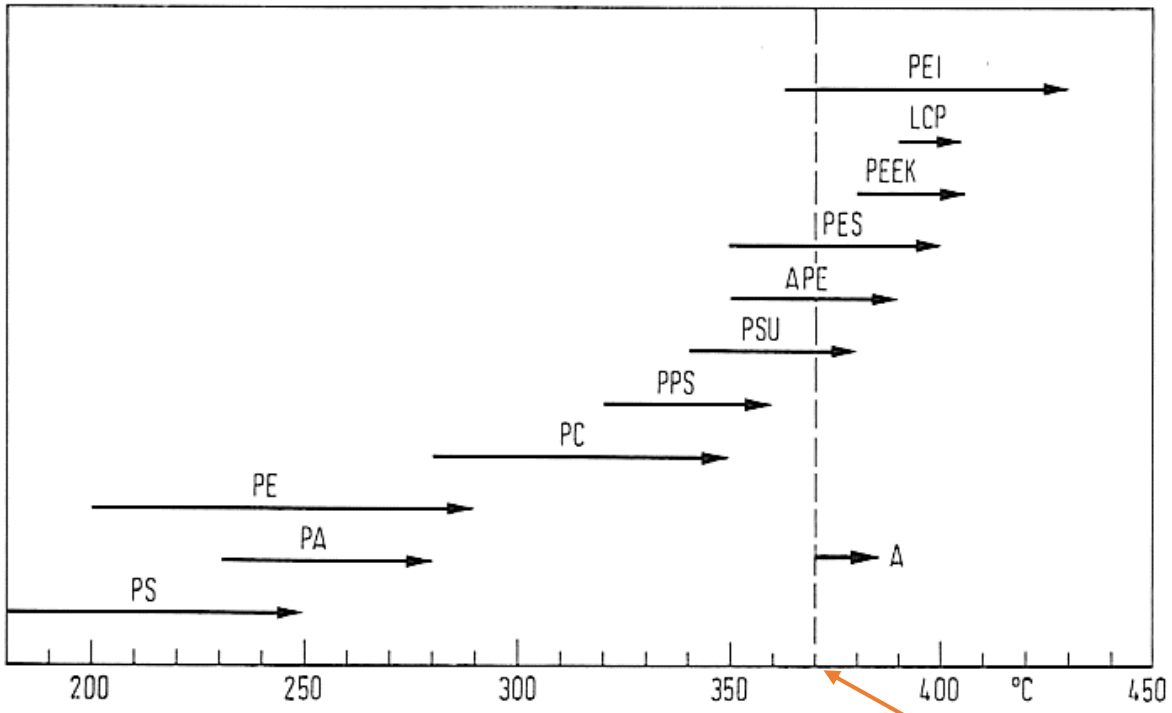
# 3-plate tool for more complicated cavity arrangements



# Pick-up robot for automotive bumper bar



# Processing temperatures for different plastics




start of steel conversion

# Processing conditions for injection moulding

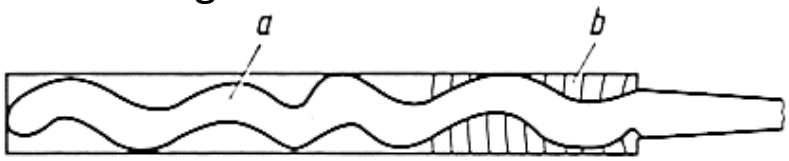
| Formmassen Kurzzeichen: | s. a. Seite | Temperaturen °C Masse | Temperaturen °C Werkzeug | Spritzdruck bar | Rückströmsperre | Verschlußdüse | Bemerkungen |
|---|---|---|---|---|---|---|---|
| PE<br>0,92 dünnw.<br>dickw.<br>0,96 dünnw.<br>dickw. | 245 | 220–260<br>180–220<br>260–300<br>240–280 | 30–70 | 600–1500 | (+) | (+) | Drücke vom Fließverhalten (Schmelzindex) abhängig |
| PP<br>TPX | 266<br>275 | 200–300<br>270–300 | 30–60<br>70 | 800–1800 | (+) | (+) | niederviskos<br>> 270 °C |
| PS<br>SAN<br>SB, ABS<br>ASA | 275 | 200–250<br>220–260<br>200–280<br>230–280 | 5–60<br>50–85<br>60–90<br>40–80 | 600–1800 | + | (+) | SB, ABS möglichst hohe Temp., aber nicht überhitzen |
| PVC hart<br>weich | 294<br>302 | 180–210<br>170–200 | 20–60<br>15–50 | 1000–1800<br>300–1500 | – | – | langsam, evtl. Intrusion, Spritzeinheit korrosionsfest |
| PCTFE<br>PFA, FEP | 311 | 200–280<br>340–360 | 80–130<br>120–180 | ca. 1500<br>300–700 | (+) | (+) | Spritzeinheit korrosionsfest |
| PMMA<br>VST 80<br>VST 110 | 318 | 150–200<br>180–230 | 50–65<br>60–90 | 700–1000<br>800–1200<br>bzw. 1800 | (+) | (+) | für hohe Ansprüche Spritzeinheit verchromen Höchstdruck für optisches Gerät |
| POM<br>und Cop | 325 | 180–230 | 60–120 | 800–1700 | + | (+) | Kristallisieren wie PA |
| PA,<br>alle Sorten | 329 | 230–290 | 40–60<br>ev. 120 | 700–1200 | + | (+) | rasch einspritzen, weite Angüsse. Feinkristallin bei hohen Werkzeugtemperaturen |
| PC | 347 | 280–320 | 85–120 | > 800 | + | (+) | Trocknen<br>4 Std./120 °C |
| PET<br>PBT | 351 | 260–280<br>235–270 | 120–140<br>30–70 | 1200–1400<br>1000–1200 | (+)<br>+ | (+)<br>(+) | bes. Sorte: mit gekühltem Werkzeug (20–40 °C glasklar amorph) |
| PPO,<br>modifiziert | 363 | 250–300 | 80–100 | 1000–1400 | (+) | (+) | langsam<br>weite Düse |
| CA, CAB | 371 | 180–230 | 40–50 | 800 | + | (+) | verchromte Spritzeinheit |

+ = zu empfehlen (+) = kann zweckmäßig sein – = nicht möglich

# Sausage type injection moulding

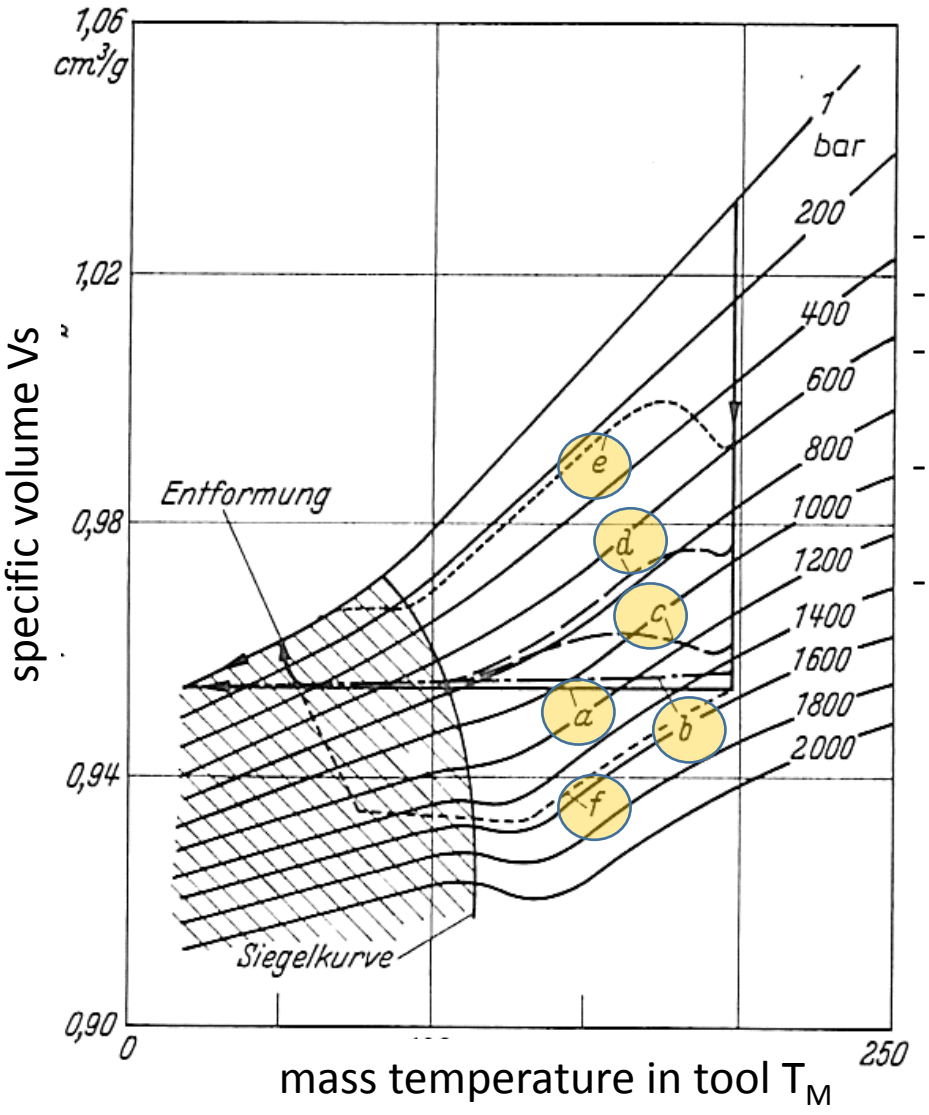
matt surface areas caused by cooling while feeding due to contact with wall

sausage



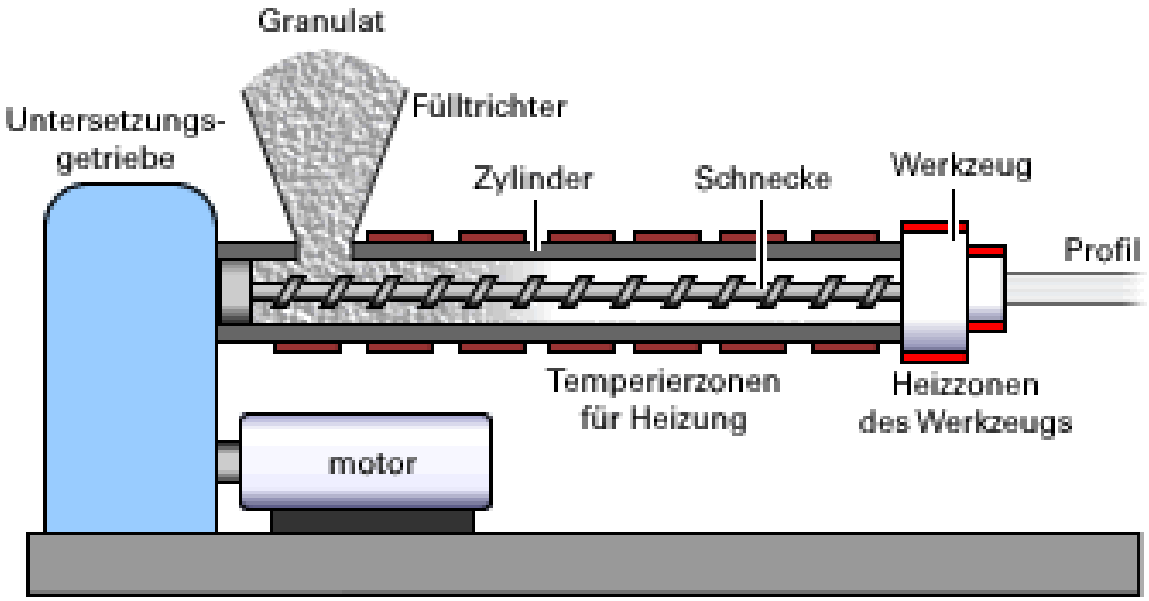

- enable the plastic mass to fill the mould continously (sometimes inside mould coatings can help such as PTFE/Ni or FEP)
- avoid sausage formation to obtain glossy surfaces
- right positioning of feeding gate and processing parameters is important

# Filling of mould and cooling in p-V-T-diagram

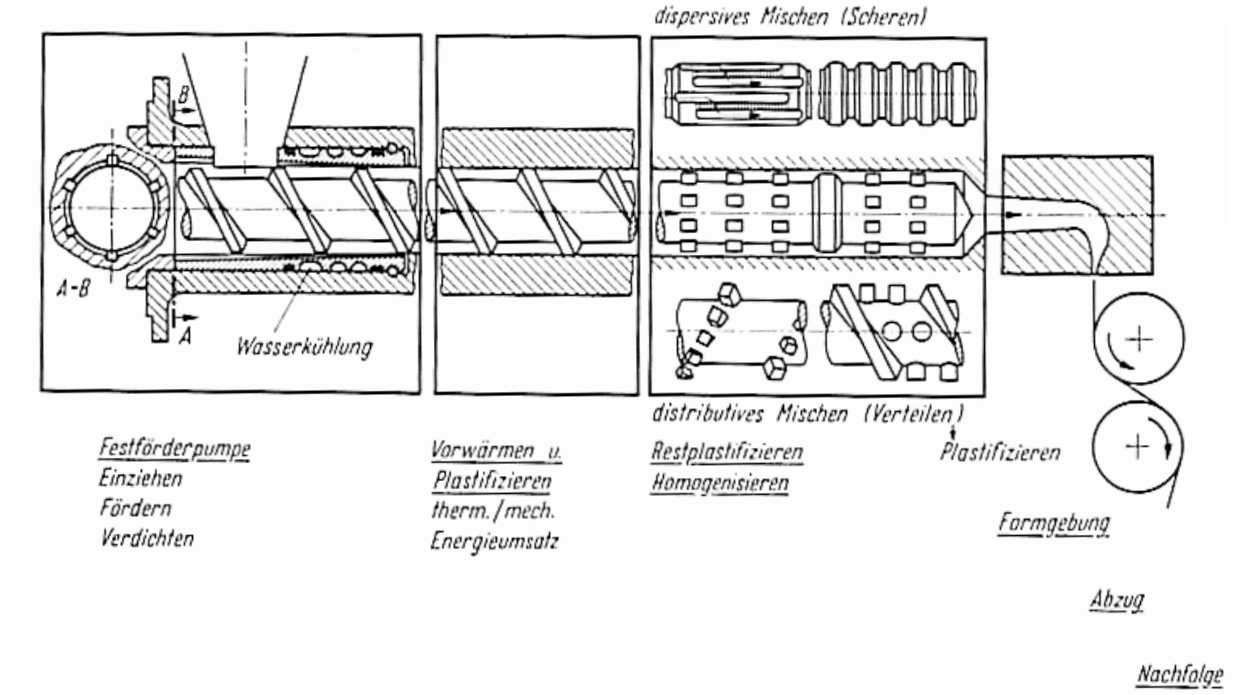



- a: isochores represent ideal behaviour
- b: behaviour at max. input pressure
- c+d: low input pressure compensated by high after pressure
- e: input and after pressure too low (disconnection at the wall)
- f: after pressure too high (part will be locked, internal stress in the part, risk of stress cracking)

# Extrusion process scheme



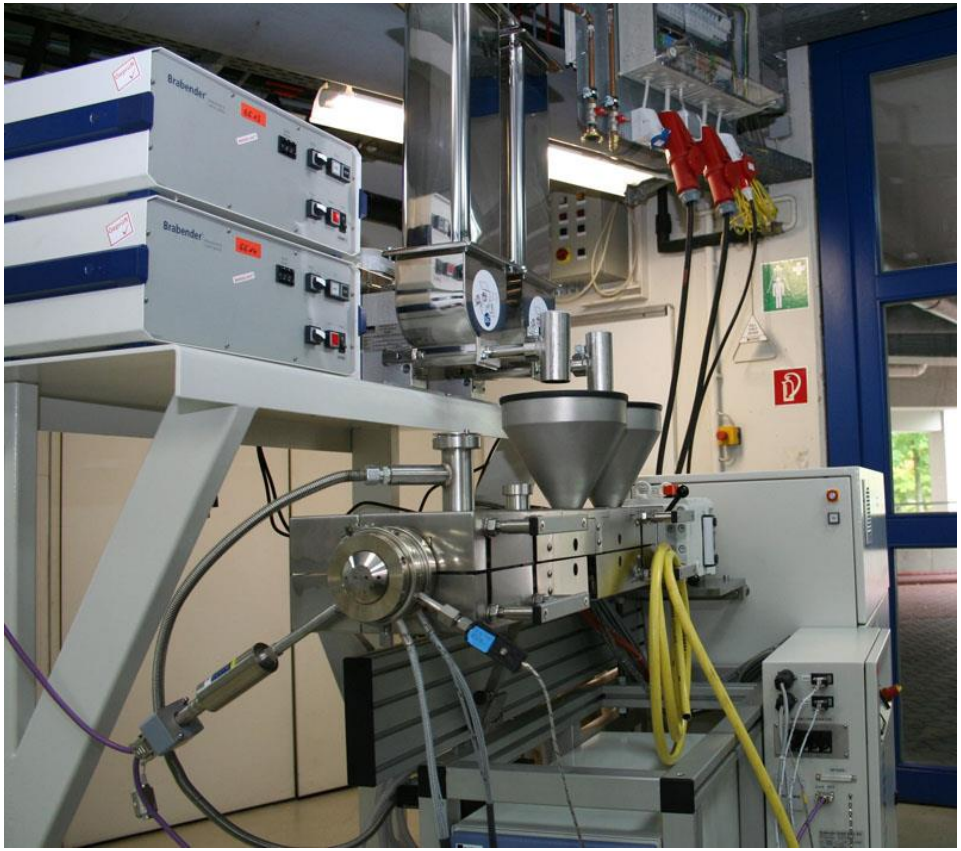
# Single screw extruder




Konzept der Einschnecke mit Feststoff-Förderung *(IKV Aachen)*

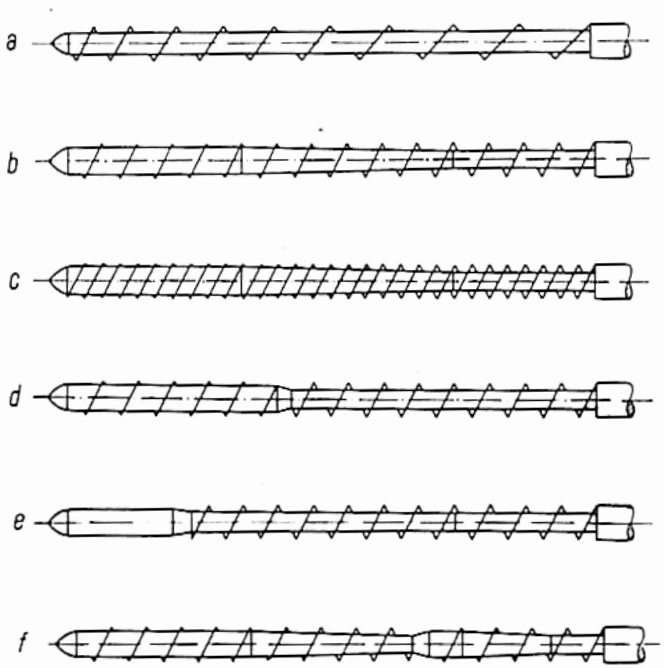
# Typical extruder

# Twin screw extruder



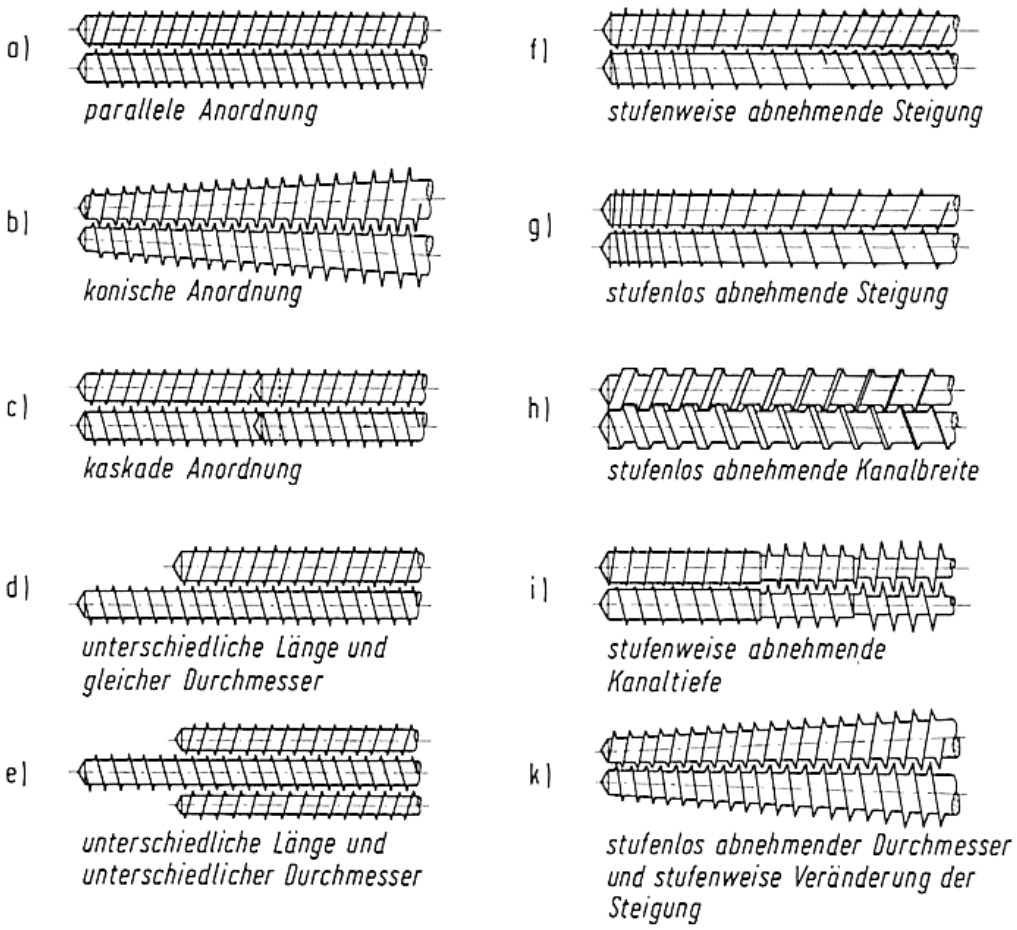
# Some examples for screws

# Examples for different screw geometries

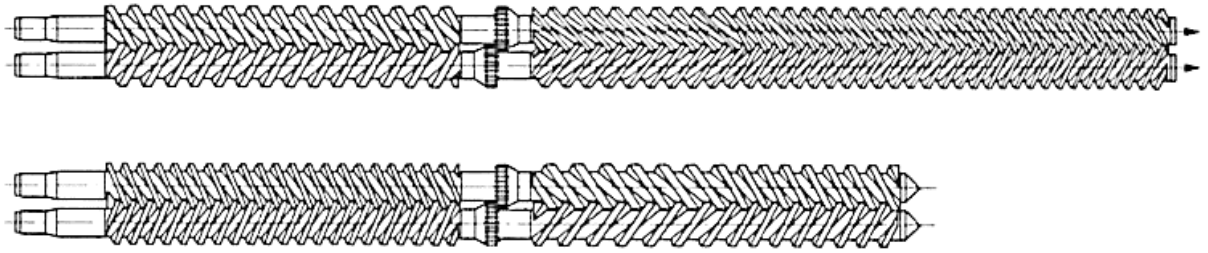



a) Eingängige Schnecke, Gangsteigung abnehmend
b) Eingängige Schnecke, Gangtiefe in der Mittelzone allmählich abnehmend („Dreizonenschnecke")
c) Zweigängige Schnecke, sonst wie b
d) Eingängige Schnecke, Gangtiefe stufenförmig abnehmend („Kurzkompressionsschnecke")
e) Eingängige Schnecke mit „Torpedo"-Kopf (glatt oder geriffelt, z. B. als „Leroy"-Scherteil)
f) Zwei eingängige Schnecken „in Reihe": Entgasungsschnecke

# Different types and arrangements of twin-screws



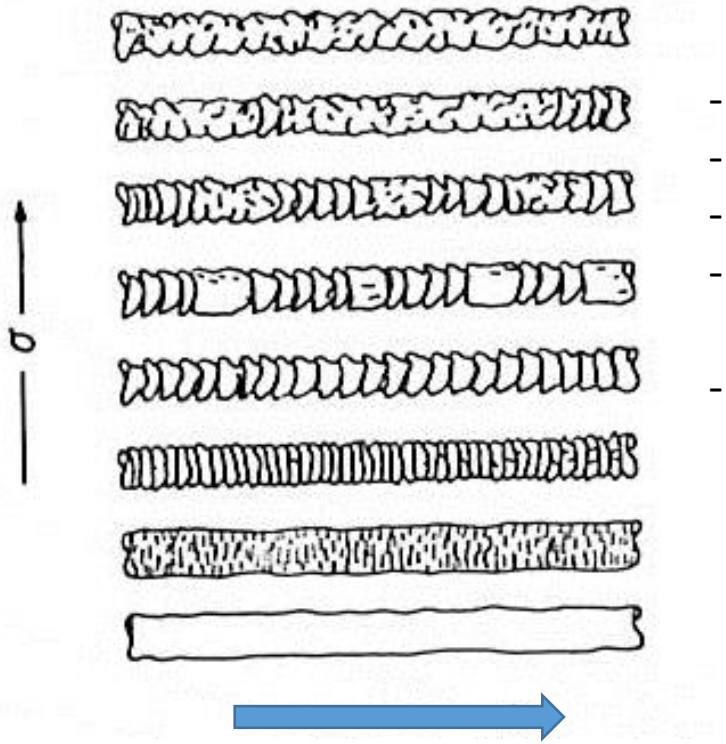
# Different types and arrangements of twin screws



Schneckenpaar mit Lochscheiben vor der Entgasungszone *(Thyssen-Plastik-Maschinen)*

# Example of an extrusion head

# „Melt fracture“ with increasing shear stress



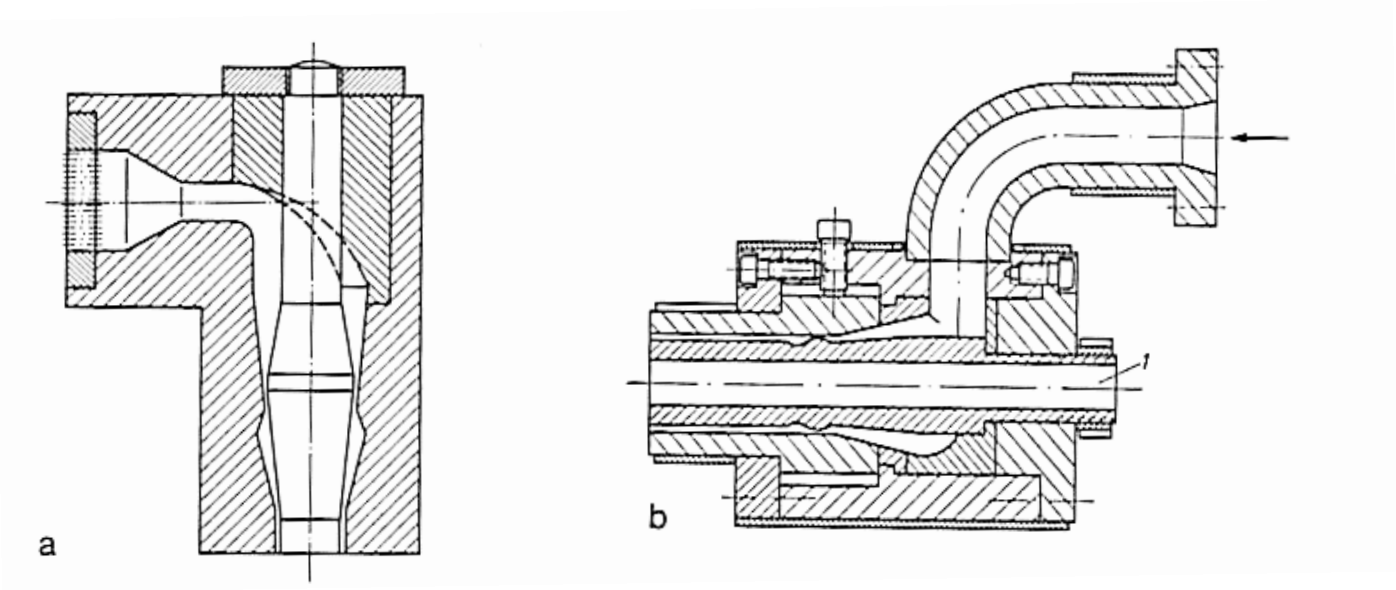

- elastic behaviour of polymer melts
- elastic vibrations during flow
- decreased damping with increasing shear stress
- loose of contact between melt and wall cause critical turbulences making melt surface rough
- during cooling surface roughness is frozen (surface looks like „fractured“)

J.L. Leblanc

# Tools for extruders to produce tubes

center sleeve type (Pinole) with lateral inlet

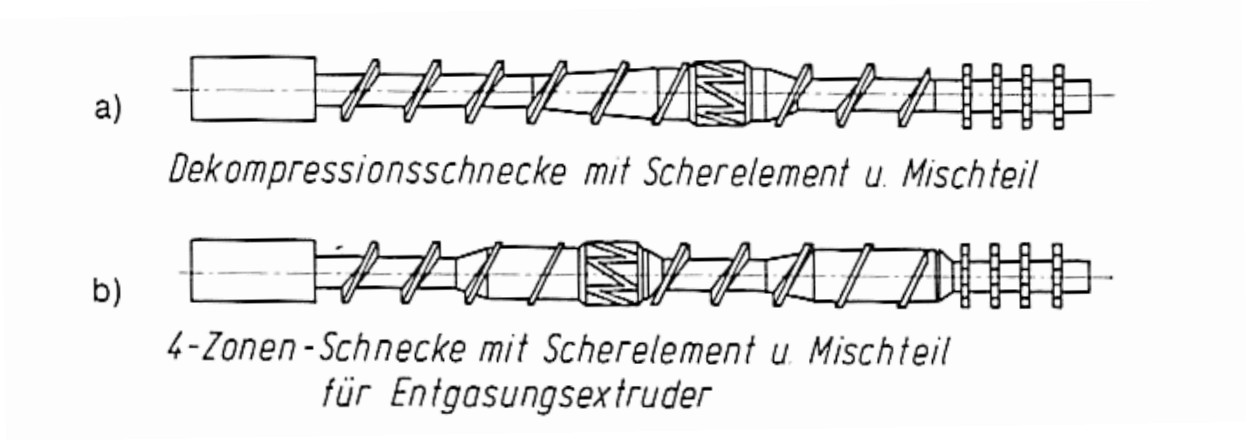
off-set tube head



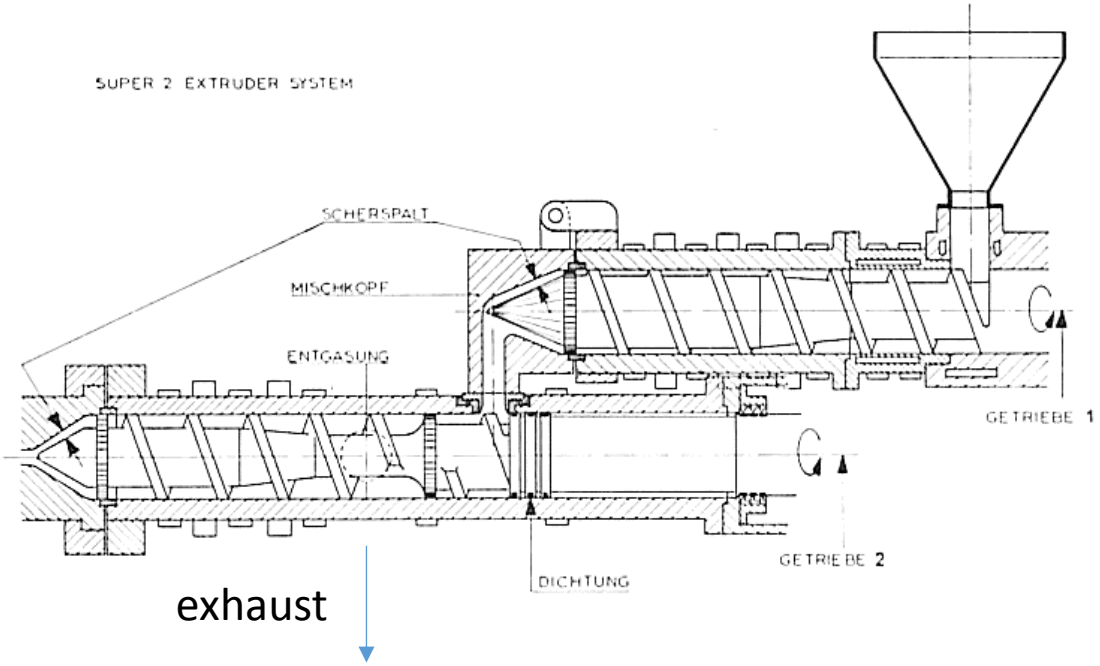
# Multi-zone-screw extruders

| | | |
|---|---|---|
| Schneckendurchmesser<br>Schneckenlänge | (über den Stegen gemessen)<br>(im Verhältnis zum Durchmesser) | D = 90 mm<br>L = 25 D |
| Einzugszone | Verdichten mit Entgasen zur Aufgabetrichter hin, allmähliches Aufschmelzen der Formmasse | $L_E$ = 10 D |
| Übergangs- oder „Kompressions"-Zone | Homogenisierung der Schmelze im Wechselspiel von Schlepp- und Druckströmung, Druckaufbau | $L_U$ = 6 D |
| Ausstoß- oder „Pump"-Zone | „Pumpen" der Schmelze gegen den Fließwiderstand des Werkzeugs im gleichmäßigen Fluß | $L_A$ = 9 D |
| Gangtiefe<br>„Kompressionsverhältnis" | der Einzugszone<br>Gangtiefen- oder Volumenverhältnis der ersten und der letzten Schneckenwindung | 12 mm<br>3:1 |

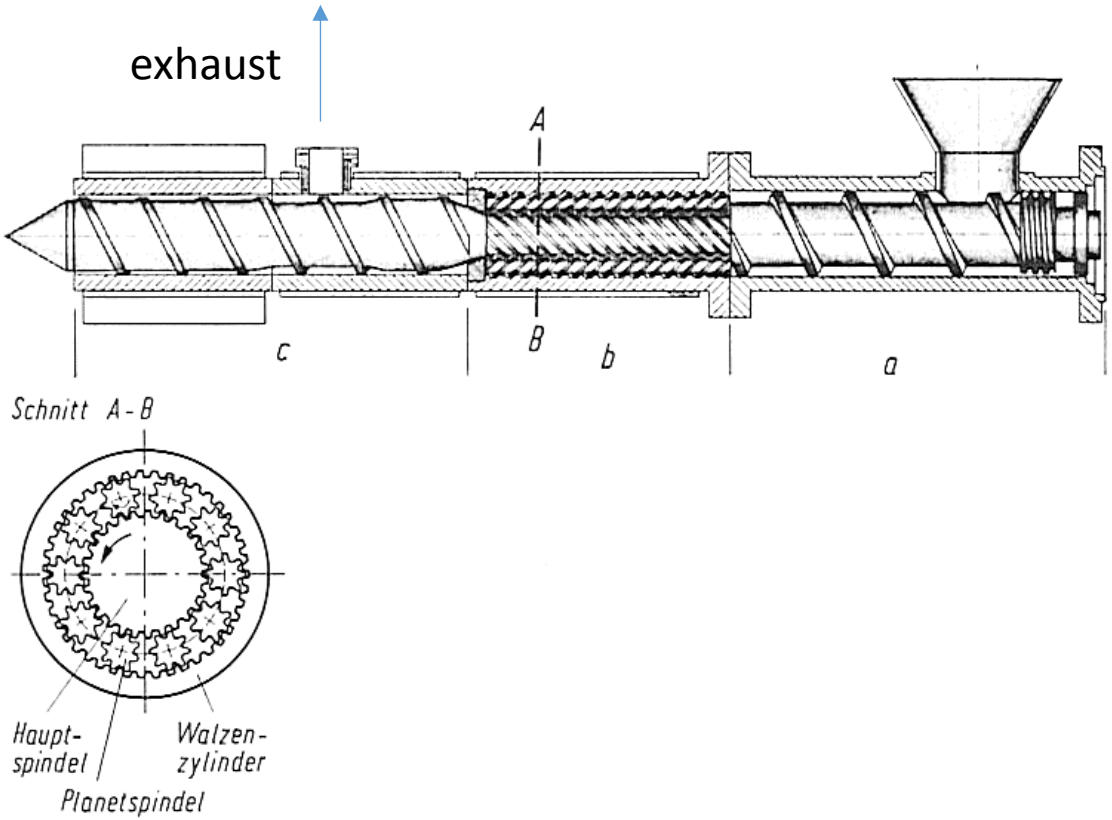
# Examples for screws having shear and mixing elements



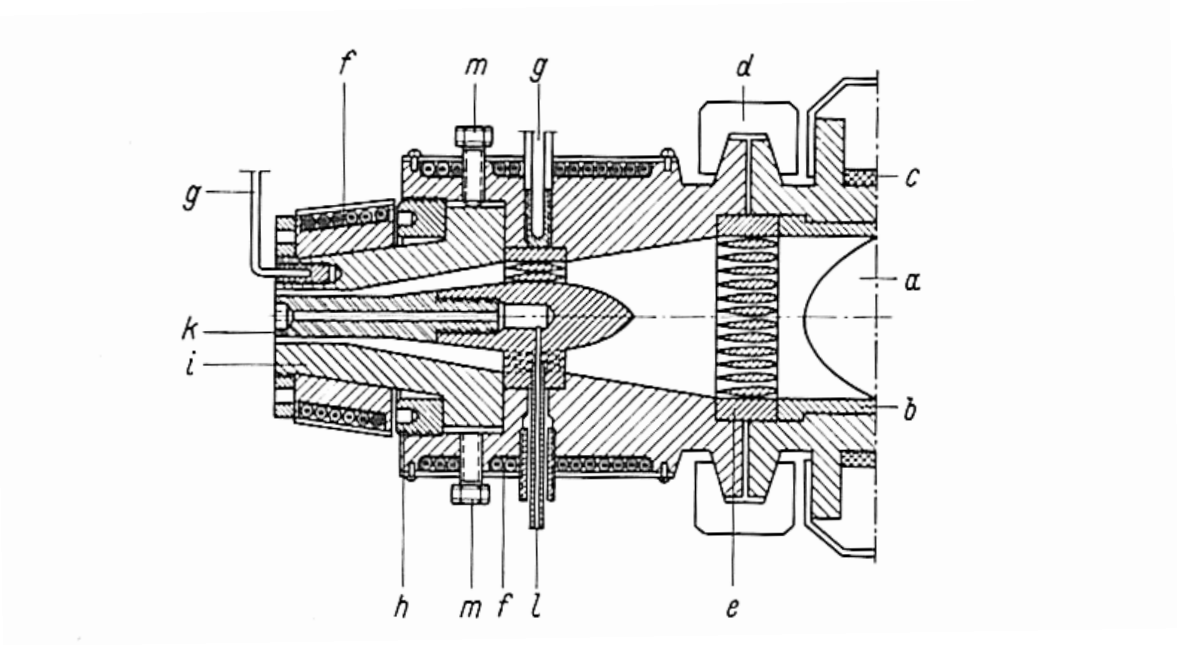
# Cascade type extruder



# Planetary-gear extruder

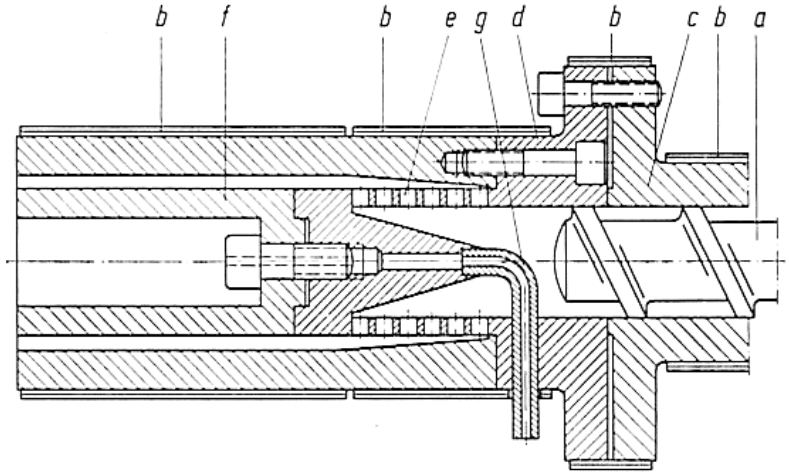


# Hollow thorn tool




direction of flow

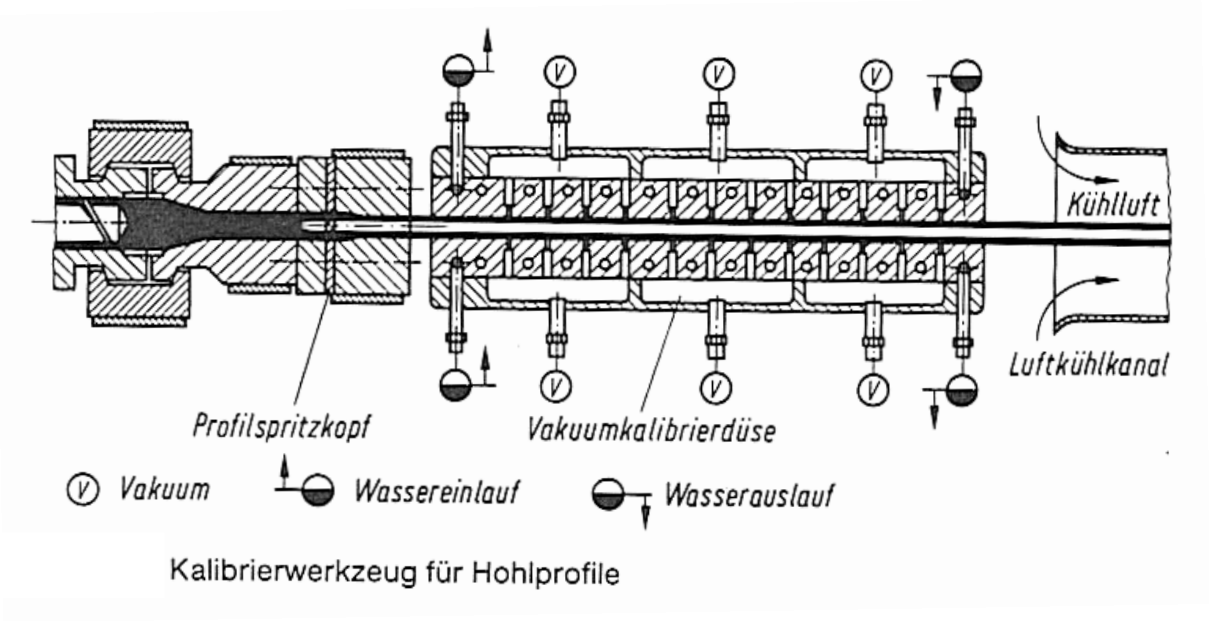
# Example for tube tool




Siebdorn-Rohrwerkzeug

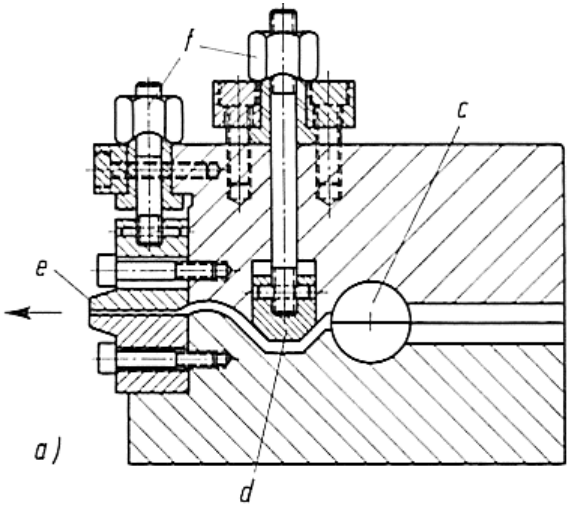
*a* Schnecke, *b* Heizung, *c* Extruderflansch, *d* Anschlußflansch, *e* Siebkorb, *f* Werkzeugdorn, *g* Druckluftanschluß

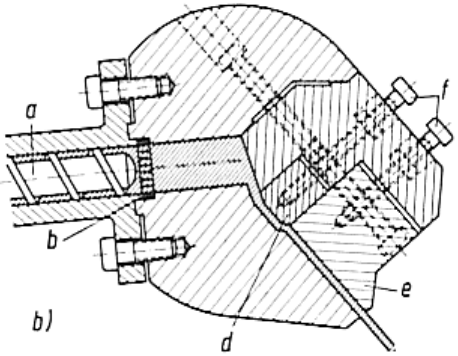
# Vacuum tank calibration set-up

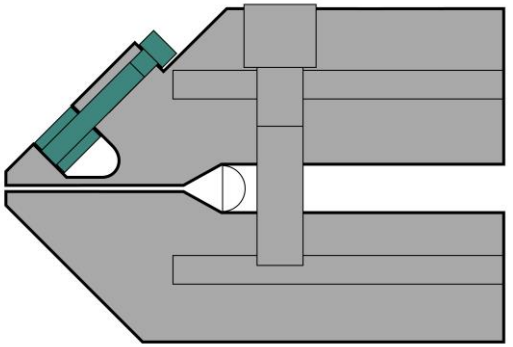



Kalibrierwerkzeug für Hohlprofile

# Slot die



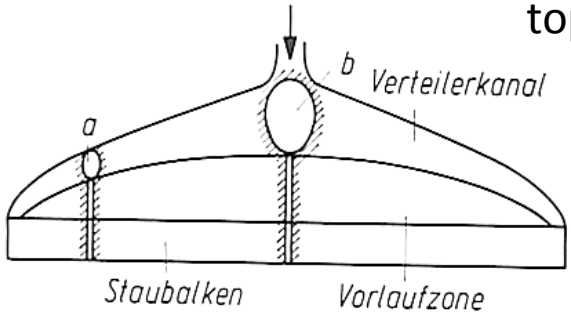



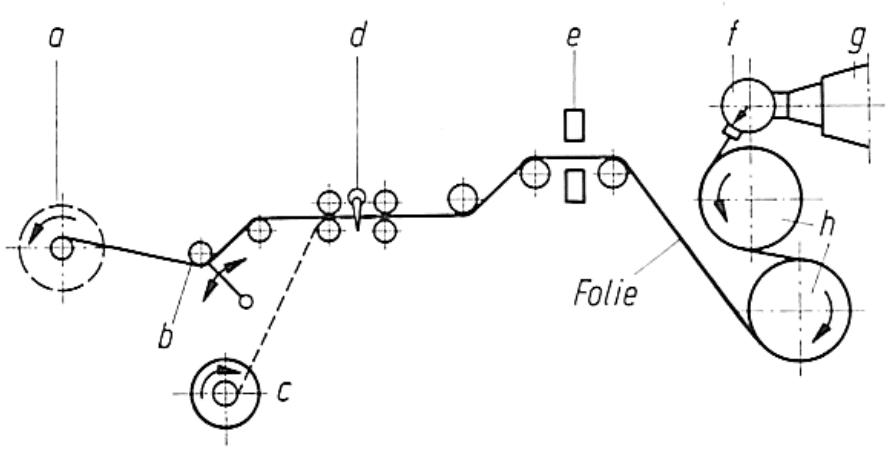
for plates

for foils

top view



# Chillroll process

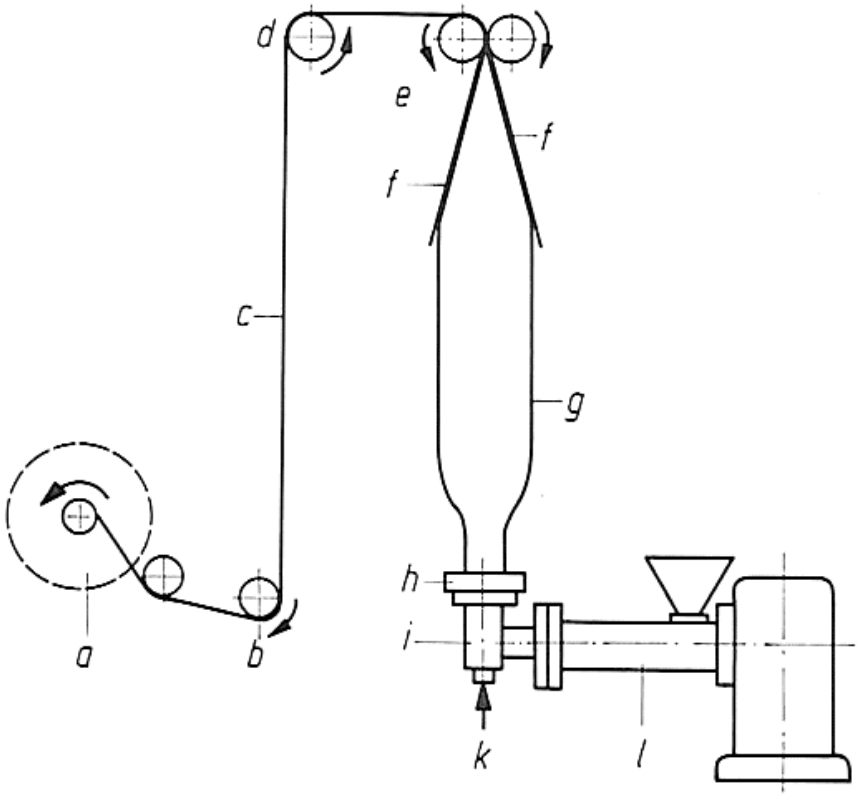



Prinzip des Chillroll-Verfahrens

*a* Folienaufwicklung, *b* Tänzerwalze, *c* Abfallaufwicklung, *d* Randbeschneidung, *e* Dickenmessung, *f* Breitschlitzdüse, *g* Extruder, *h* Kühlwalzen

# Foil extruder

# Foil production via tube

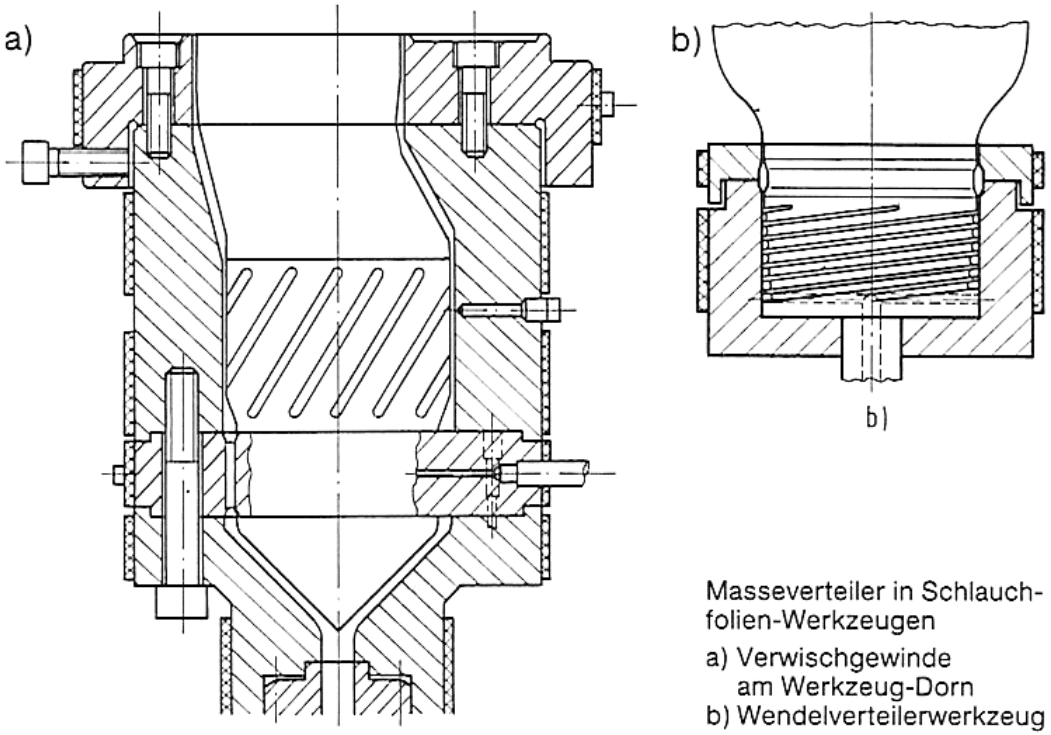



Schlauchfolienanlage, senkrecht nach oben arbeitend

*a* Aufwicklungsvorrichtung mit Spannrolle, *b* Umlenkwalze, *c* doppelt flachgelegte Folie (unaufgeschnitten), *d* Umlenkwalze, *e* Quetschwalzen, *f* Leitbleche, *g* Kunststoffschlauch, *h* Kühlung, *i* Blaskopf, *k* Luftzuführung, *l* Extruder

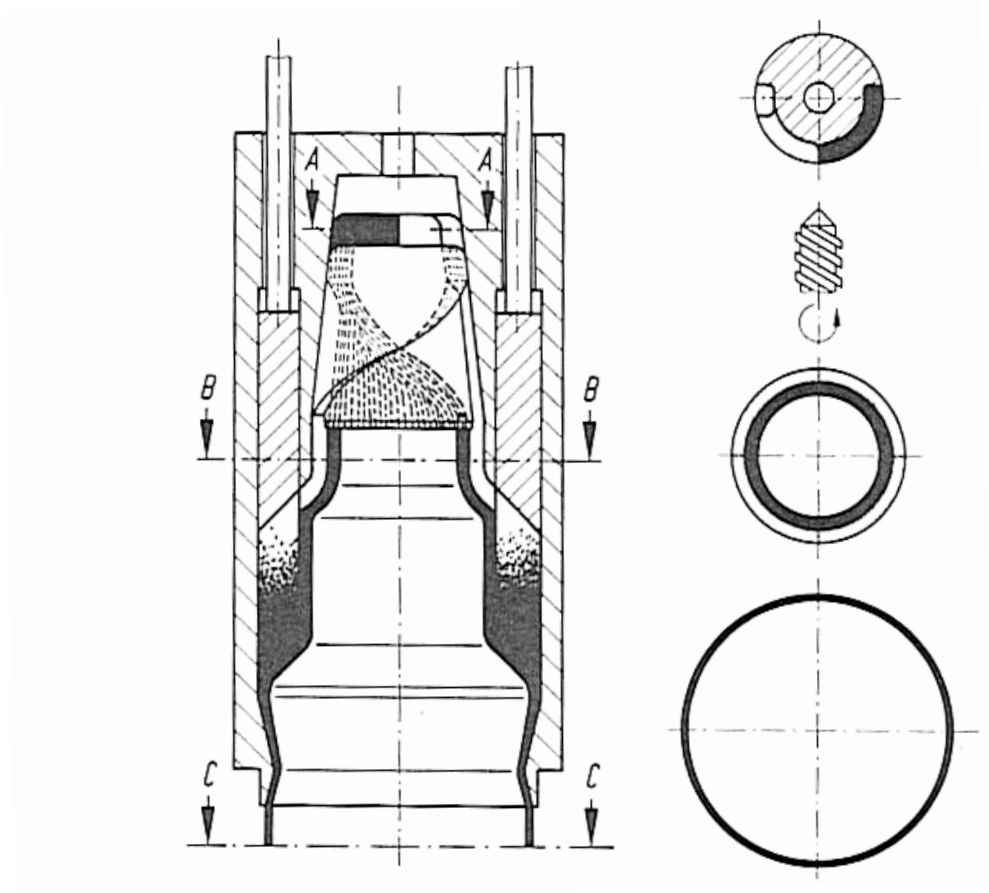
Saechtling

# Mass distribution in tube foil tools

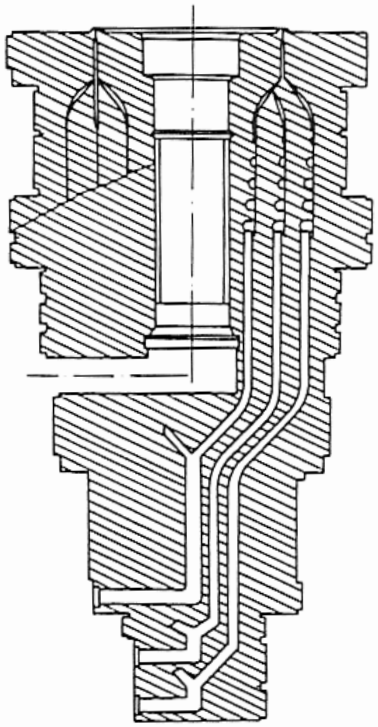



Masseverteiler in Schlauch-folien-Werkzeugen
a) Verwischgewinde am Werkzeug-Dorn
b) Wendelverteilerwerkzeug

# Tubular ram accumulator with center sleeve (Pinole)

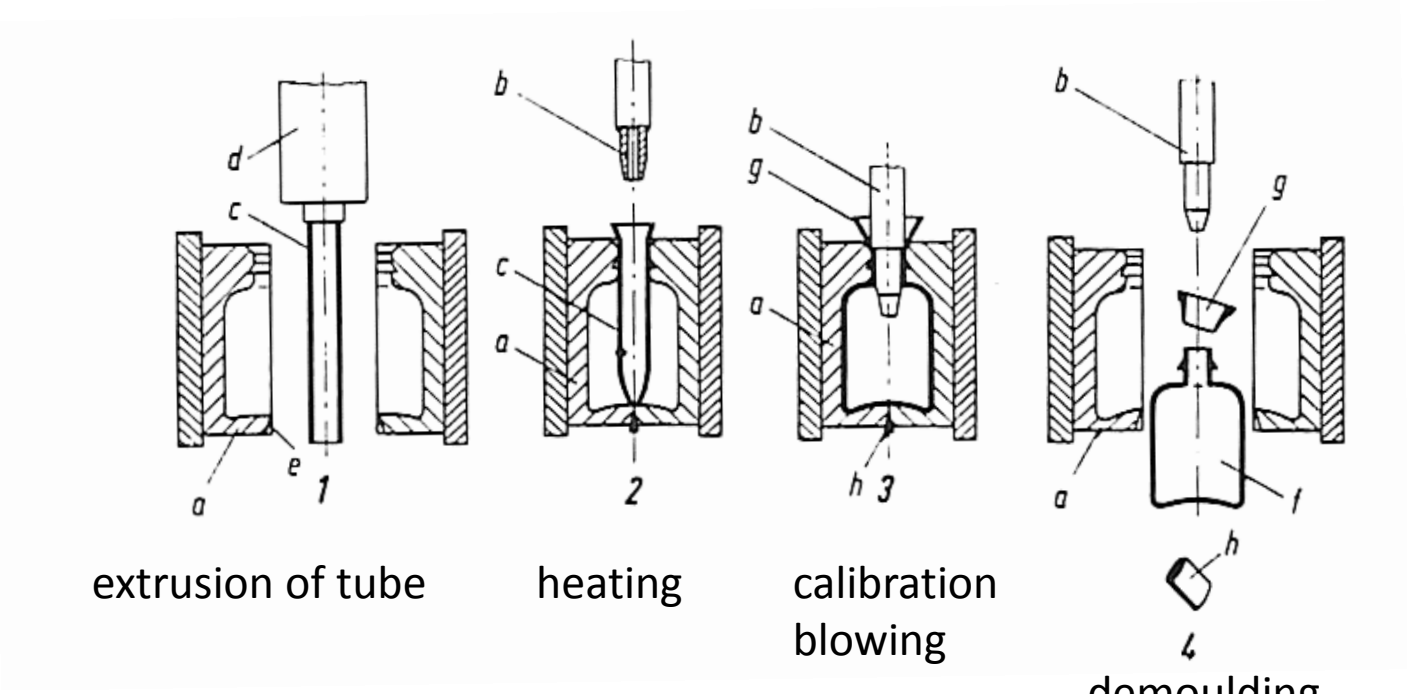


# Co-Extrusion of foils



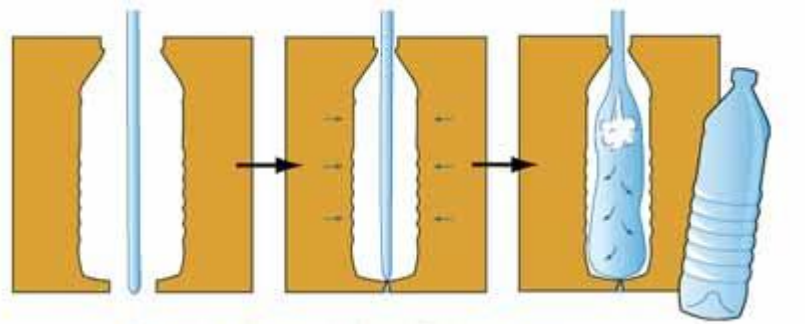
Dreischicht-Coextrusions-Blasfolien-werkzeug (Battenfeld)

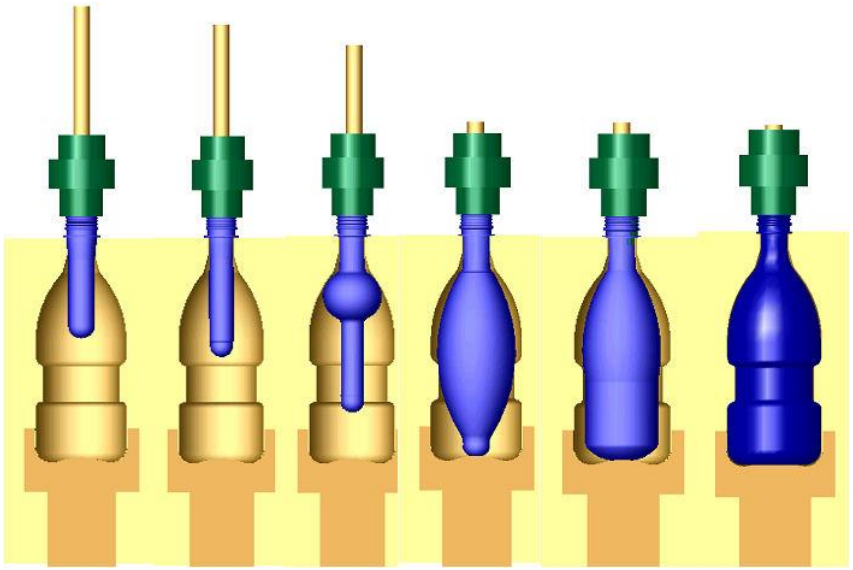
# Extrusion blow moulding



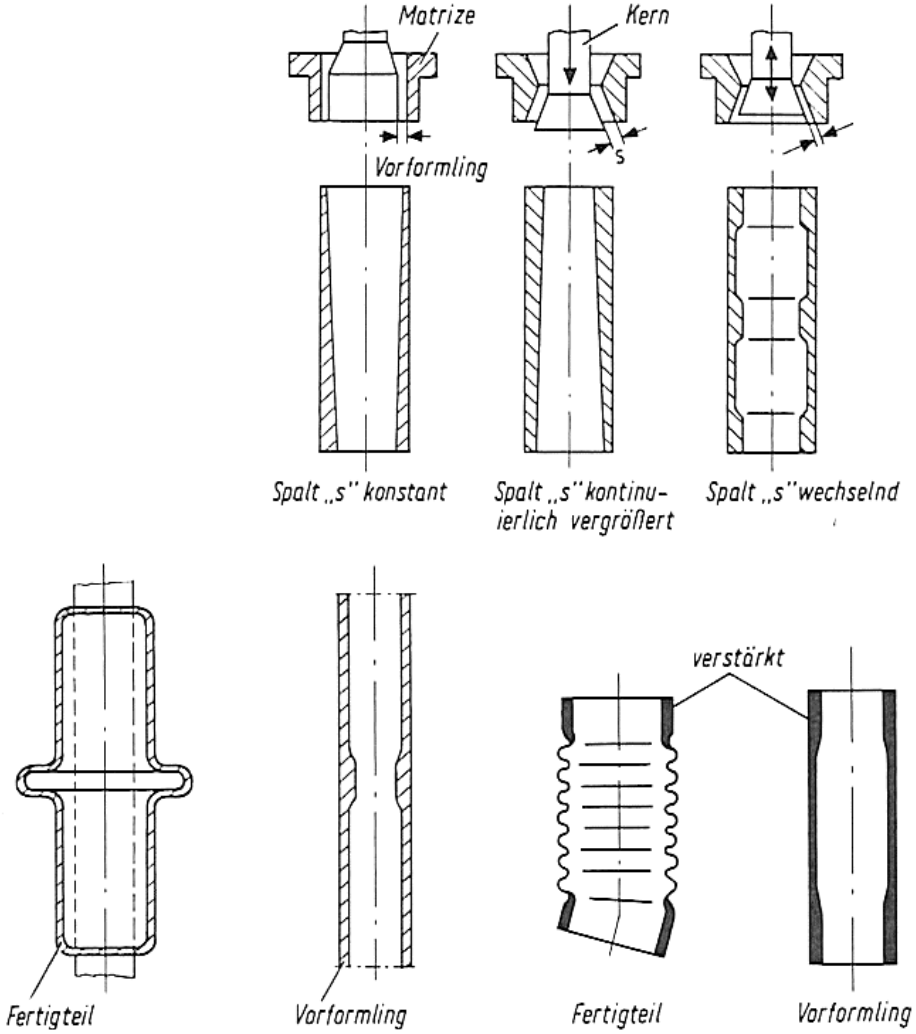

extrusion of tube heating calibration blowing demoulding

# Extrusion blow moulding

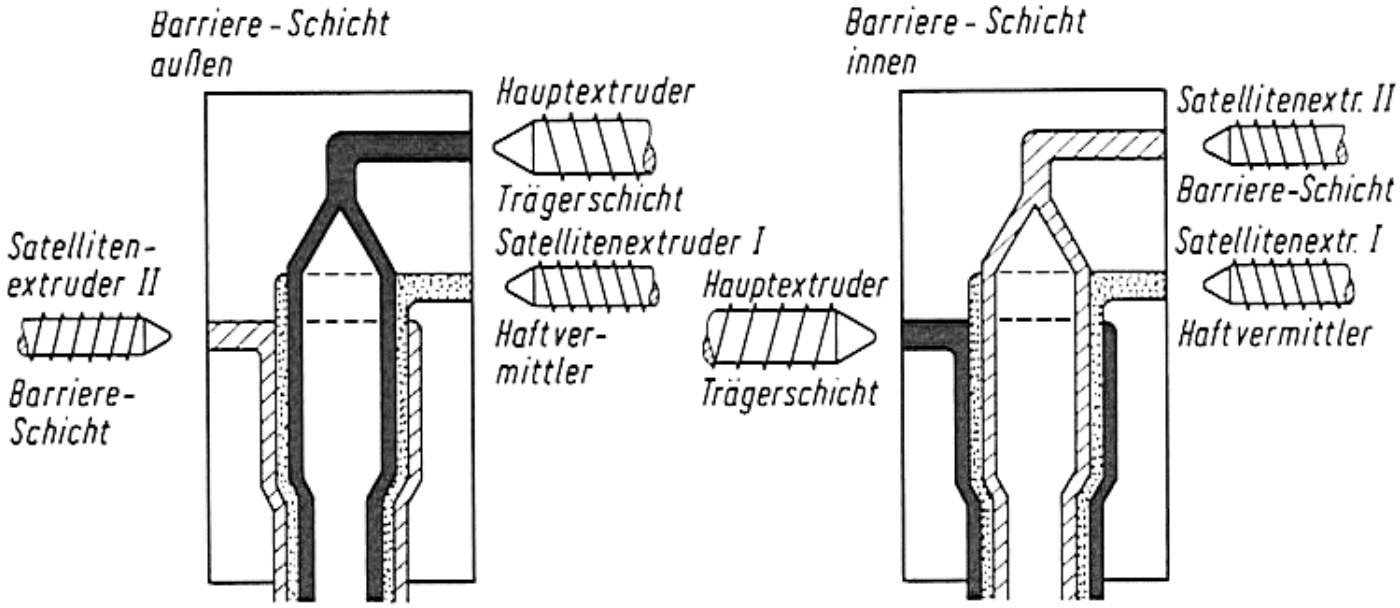




# Principle of the wall thickness calibration



# Barrier properties for bottle extrusion blow moulding



# 4-operation station fow blow moulding