PACKALL

PackAlliance:
European alliance for innovation training
& collaboration towards future packaging

Linking Academy to Industry.

Training program: modules

- Eco-design & novel manufacturing processing
- **New materials and biomaterials**
- Citizen and Consumer Engagement
- Residue management and valorisation

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Plastics Packaging

Plastic packaging is mainly composed of one or more plastic materials, whether of fossil, renewable or recycled origin.

A distinction is made between:

- **Rigid packaging**, characterized by a certain shelf life and resistance to deformation. The main component of rigid packaging is generally thicker than 300 microns. Example of rigid packaging: bottles, cans, jars and trays.
- **Flexible packaging**, which most often combines different thin materials with complementary properties to package food, pharmaceutical, hygiene and beauty products, maintenance products, etc. and guarantees product preservation and protection. They represent also an effective communication vector (printing…).

They are two types:

- **Complex,** i.e. composed of films of several materials, such as plastic, aluminium, paper. Example: a yoghurt pot lid (aluminium film + plastic film).
- **Monomaterial**, i.e. composed of several plastic films. Example: a bag for grated cheese.

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Rigid packaging

Plastics Packaging is used for packaging a variety of items i.e. fragile or non-perishable products. Plastics packaging materials are used to cover the plastic related materials or products.
Without packing, these sophisticated goods with low shelf life will be easily affected by climatic conditions and eventually result in their malfunction or destruction. This packaging is done in such a way that no air or dust can sneak in and affect the goods.

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Types of plastics packaging

The most common types of plastics used and their applications are illustrated in the following table:

Polymer Types	Examples of applications
Polyethylene Terephthalate	Fizzy drink and water bottles. Salad trays
High-Density Polyethylene	Milk bottles, bleach, cleaners and most shampoo bottles.
Polyvinyl Chloride	Pipes, fittings, window and door frames (rigid PVC). Thermal insulation (PVC foam) and automotive parts.
Low-Density Polyethylene	Carrier bags, bin liners, and packaging films.
Polypropylene	Margarine tubs, microwaveable meal trays, also produced as fibres and filaments for carpets, wall coverings, and vehicle Upholstery.
Polystyrene	Yoghurt pots, foam hamburger boxes and egg cartons, plastic cutlery, protective packaging for electronic goods and toys. Insulating material in the building and construction industry.
Unallocated References	Any other plastics that do not fall into any of the above categories - for example, polycarbonate which is often used in glazing for the aircraft industry

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Benefits of Plastics Packaging

Here are the benefits of choosing plastics packaging:

- Lightweight
- Durable
- Sustainable
- Cost-effective
- Versatile

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Plastics Packaging Process

- ✓ **INJECTION** is best suited to long production runs (several hundred thousand). Accuracy within one millimetre makes the packaging suitable for all existing automated systems.
  It also allows the design of complex forms for large or small customers' industrial machinery and/or supply chains: from 1Kg units (small trays) to those of much greater weight (pallets and pallet crates).

- ✓ **THERMOFORMING** meets many requirements:
  Thermoforming technology limits tooling costs, making it suitable for medium production runs and even complex design for some units. It provides outstanding impact resistance, giving these products a long lifespan (up to 10 years).

- ✓ **EXTRUSION** is a low tooling cost technology that is suitable for short made-to-measure runs (a few hundred) as well as long runs (e.g. hundreds of thousands of spacers). It allows for different materials and multiple shapes adapted to all customer requirements (e.g. complete solutions containing textile liners).

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Injection Molding Machine

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Composition of Injection Molding Machine

- Clamping unit
- Injection unit
- Hydraulic control system (for hydraulic press)
- Basement
- Control unit

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CLAMPING UNIT

The function of the clamping unit is to open and close the mold (which we could define as a tool) and to be able to eject the part from the mold by extraction cylinder.

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INJECTION UNIT

The function of the injection unit is to make the solid plastic material (PELLETS) processable and inject it into the mold to obtain the desired product.

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HYDRAULIC CONTROL SYSTEM (hydraulic press)

The hydraulic control system is used to supply the hydraulic oil in all parts of the press where it is required.

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BASEMENT

It has the task of resisting the stresses due to all stages of the process

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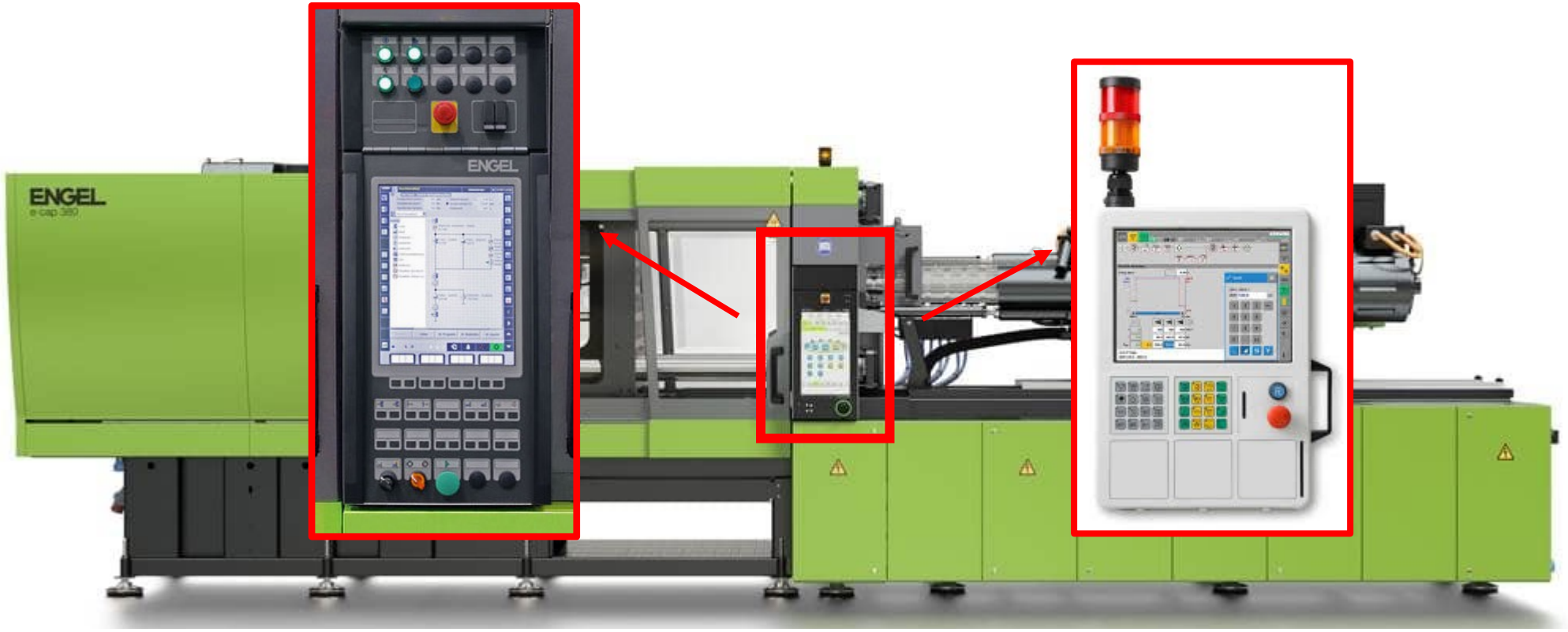
CONTROL UNIT

The control unit allows the control of the injection machine, therefore it is the interface between the operator and the injection molding machines.



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Composition of clamping unit

- ***Platen:***

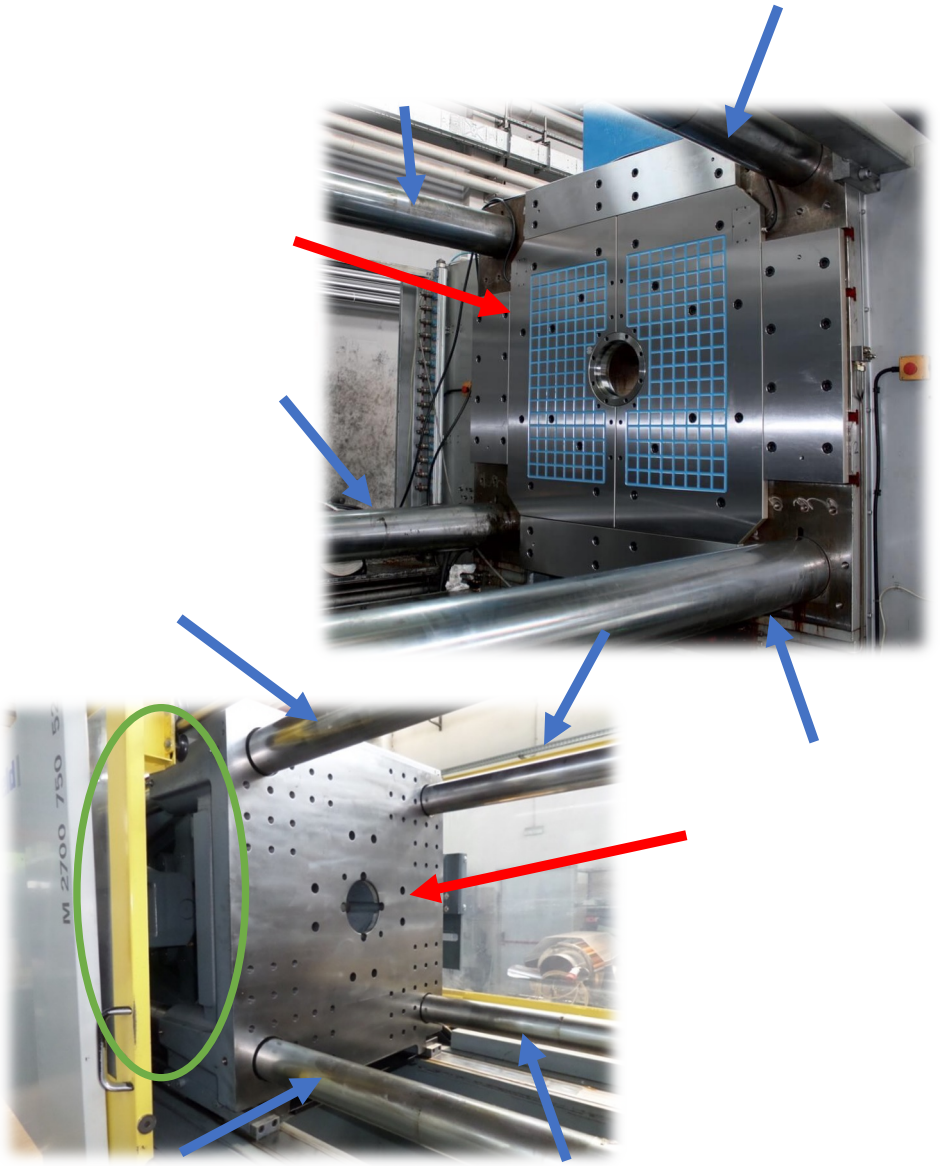
  Stationary and moving platen where the mold will be fixed.

- ***Tiebars:***

  They guide the movement of the moving plate.

- ***Closing device :***

  Used to move the moving plate and to generate the necessary force to keep the mold closed.



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Function of clamping unit

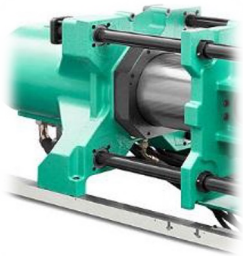
1) Open and close the two mold halves as quickly as possible

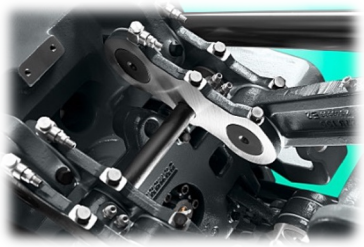
2) Develop the closing force, to react to the pressure of the material during injection.

Main clamping unit

1) Cylinder (Hydraulic)

2) Toggle (hydraulic/electric)





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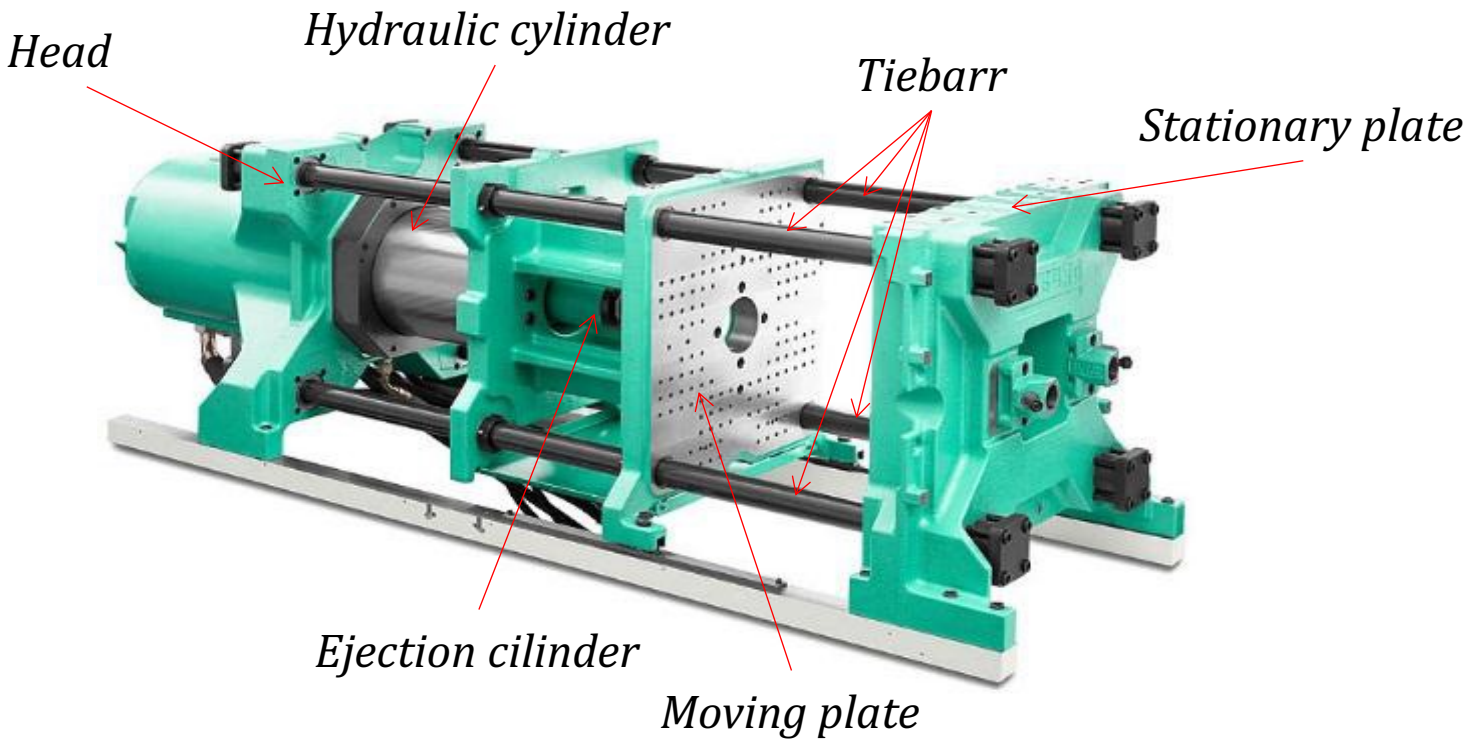
Cylinder (Hydraulic)

The simplest method to move the moving plate is to insert a hydraulic cylinder between the head of the locking unit and the moving plate itself.
It's the cylinder that moves the moving plate and develops the clamping force.



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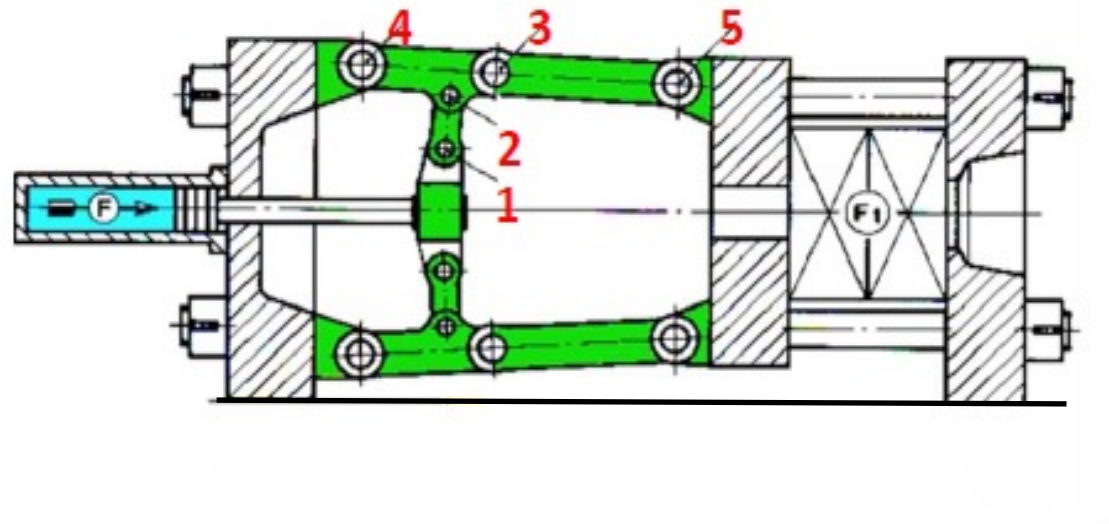
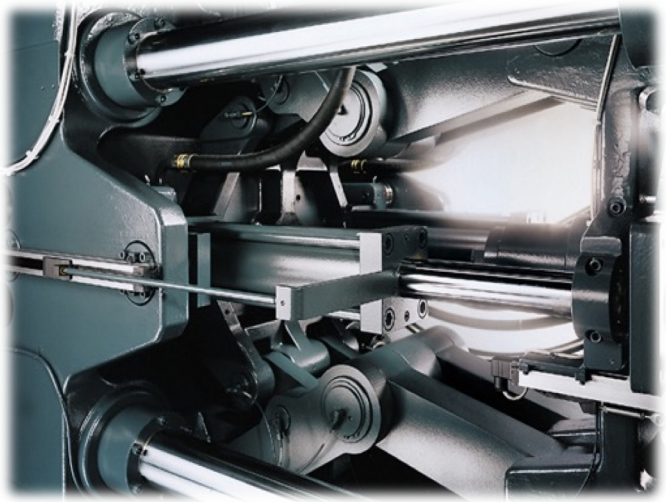
Toggle (double whit 5 points)

This system uses the principle of irreversibility of the arch with three aligned hinges.

It’s made by two levers connected to each other and to the plates by means of hinges and a jack acting on the central hinge.





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Clamp Controls

- Clamp force
- Clamp closing and opening speeds
- High and low pressure during mold closing and lock-up

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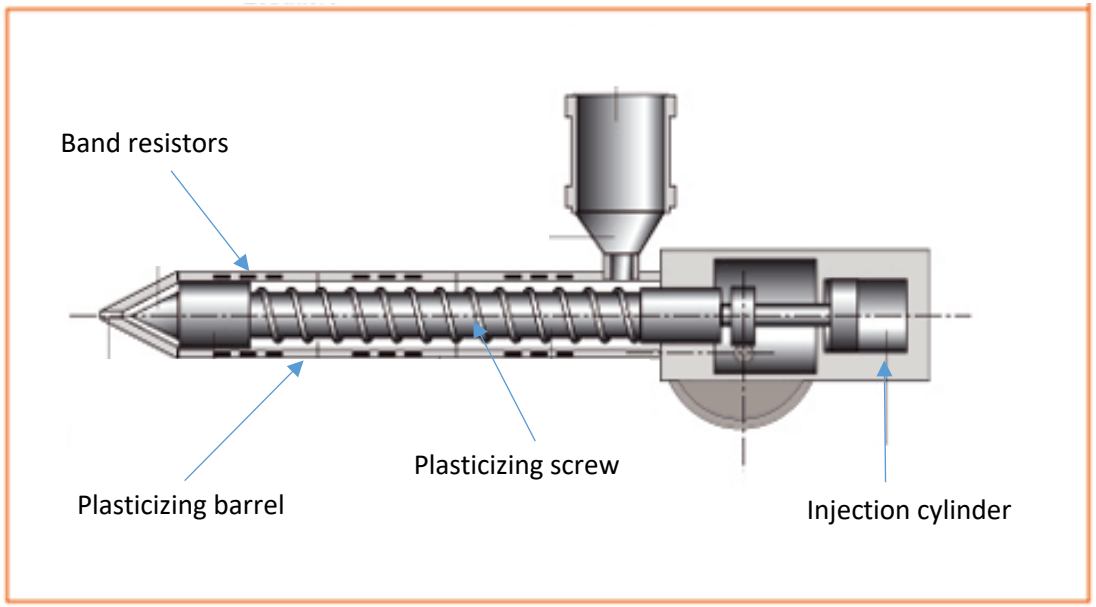
Composition of injection unit

The injection unit is essentially made up of three parts:

1. Plasticizing screw (reciprocating screw)
2. Plasticizing barrel
3. Band resistors

Then we have :

- Electric or hydraulic motor, which controls the rotation of the screw
- Injection cylinder, to transfer the material into the mold.



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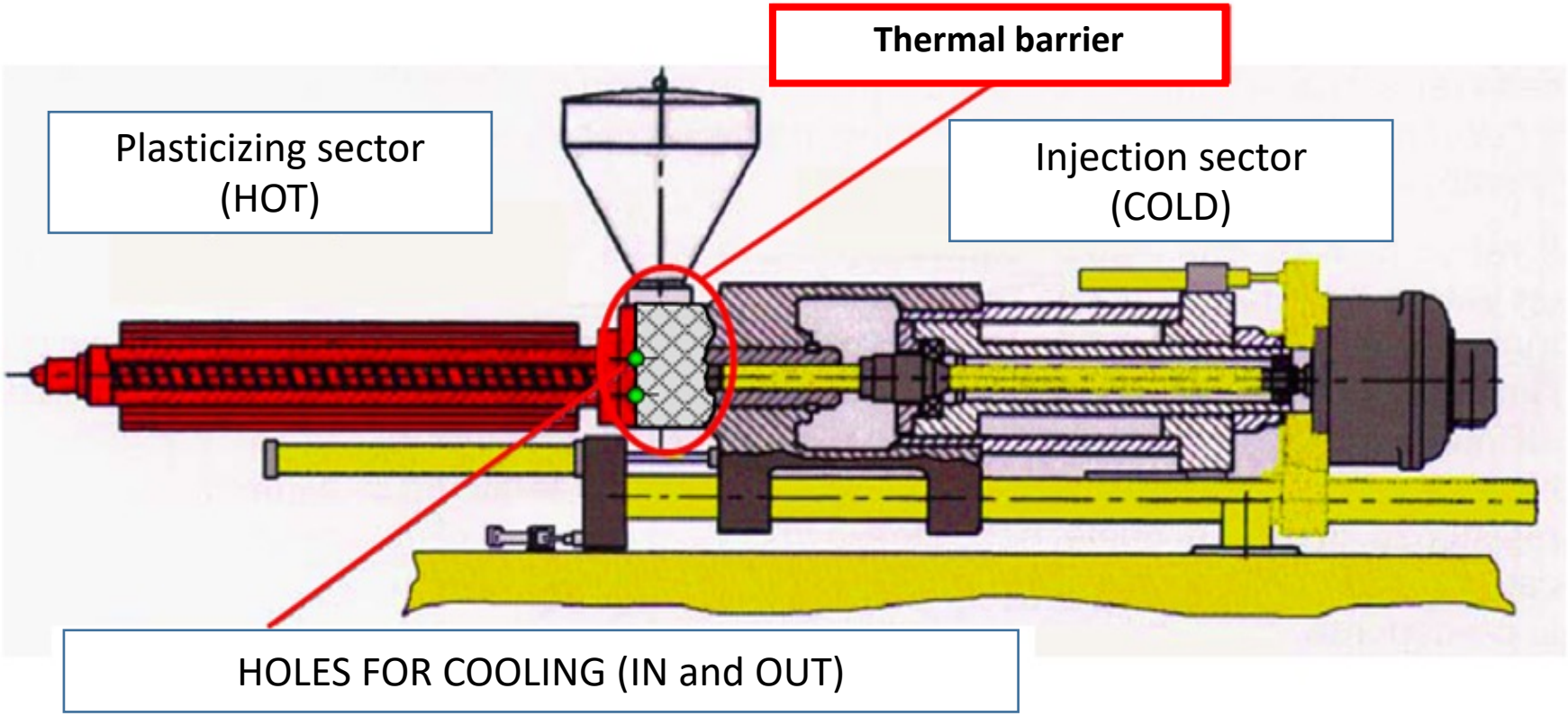
Thermal management



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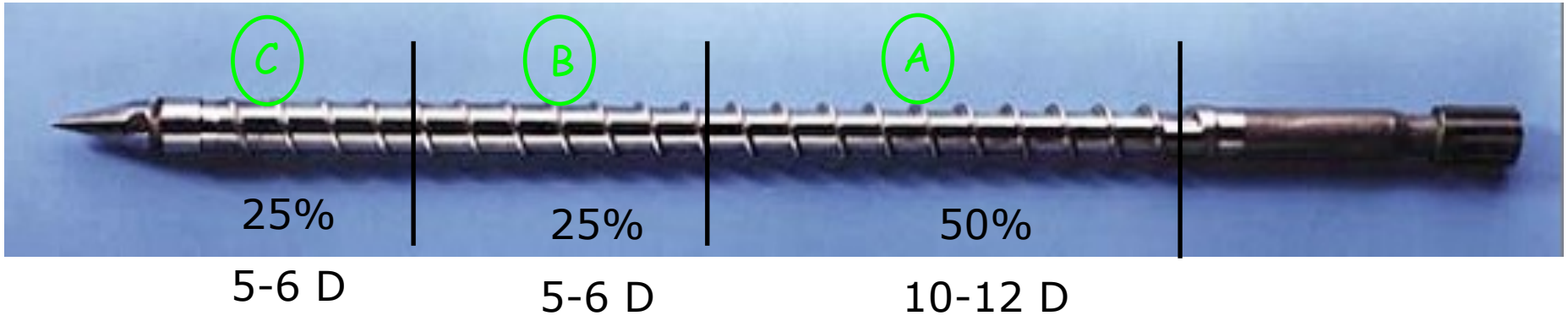
Plasticizing screw



Divided into 3 zones:

A. **FEEDING** → Constant core diameter - receives the solid material.

B. **TRANSITION** → Increasing core diameter - to recover the space due to the change of state of the material.

C. **METERING** → Constant core diameter - to improve homogenization of the melted material.

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Function of plasticizing screw

1) Transform the polymer from the solid state to the fluid state by means of :
   - ✓ The heat of the electric resistances
   - ✓ Functional friction caused by screw turns and back pressure

2) Transfer the material to the accumulation chamber
   - ➢ The material is accumulated in the front of the cylinder
   - ➢ The hydraulic cylinder can apply pressure during dosing (back pressure)

3) Inject the material into the mold.

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Function of plasticizing screw

In the plasticization process, the amount of heat necessary for the heat treatment of the material has two distinct and separate sources:

"THERMAL" HEAT SOURCE

"MECHANICAL" HEAT SOURCE

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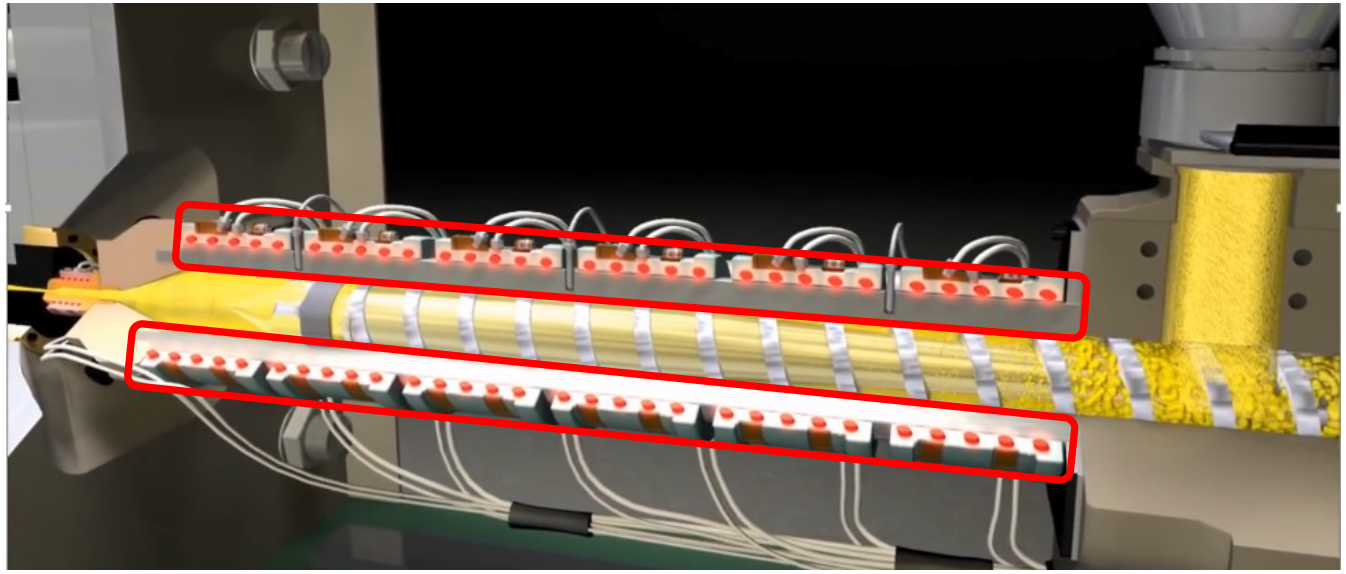
Function of plasticizing screw

"THERMAL" HEAT SOURCE

Provided by electrical resistances placed outside the plasticizing cylinder.
It has a great influence on the material near the cylinder wall and lower on the screw wall.



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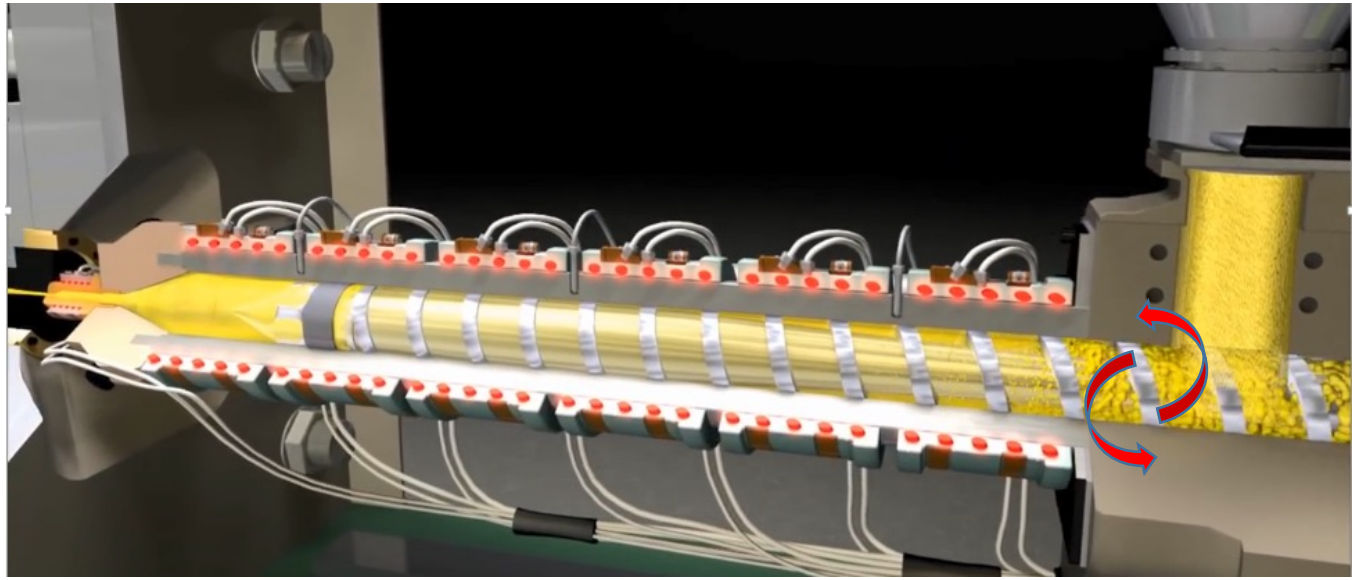
Function of plasticizing screw

"MECHANICAL" HEAT SOURCE

Due to the friction of the material in its sliding and to the compression during the plasticization phase, it transfers and uniformly distributes the heat generated within the entire mass of the treated material.



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Function of plasticizing screw

FEEDING

The plastic material is transported and advanced inside the plasticizing cylinder by heating it up to a temperature that makes it "rubbery".

THERMAL

MECHANICAL

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Function of plasticizing screw

TRANSITION

The thermal energy, of mechanical and hydraulic origin, in addition to the electrical energy applied by the cylinder, takes place in a short time and depends on the compression ratio of the screw and the length of the compression zone.

THERMAL

MECHANICAL

The plastic material and any “additives”, heated in the feeding area, are compressed and mixed to obtain a physically and thermally homogeneous mass.

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Function of plasticizing screw

METERING

The plastic material is subjected to a mechanical action of mixing and thermal action of dynamic origin.

THERMAL

MECHANICAL

This allows to reach the optimal molding temperature, typical of each material, but dependent on the characteristics of the piece to be made.

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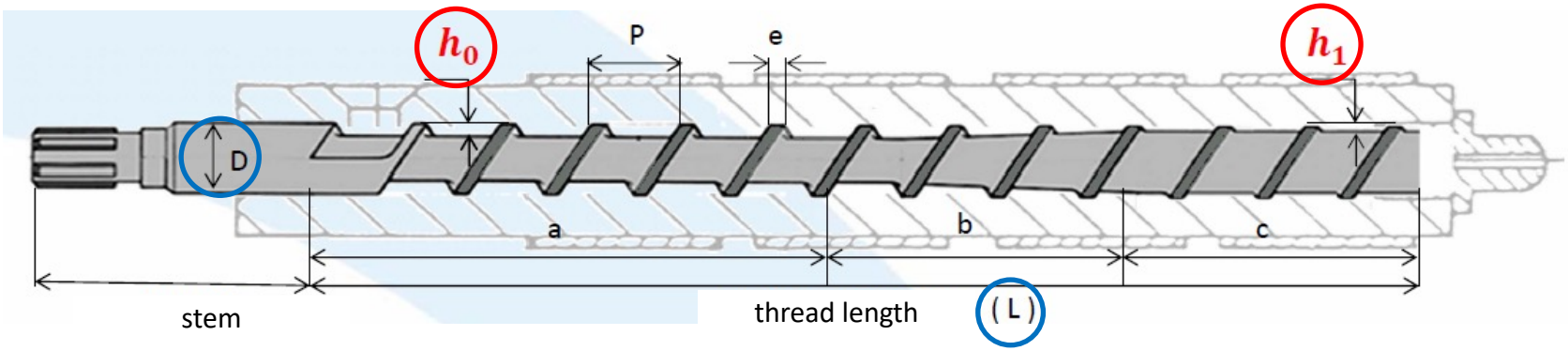
Basic parameters



1. **L/D ratio (Length / Diameter):**

It's the physical dimensions of the screw: the greater it's value, the longer the path that the material must travel between the entry into the cylinder and the injection nozzle.
Generally 20-24 L / D.

2. **COMPRESSION ratio :**

Defined as the ratio between the height of the thread in the feeding area (h_0) and that of the metering (h_1).

This ratio is lower in screws for amorphous polymers and higher in screws for crystalline polymers.

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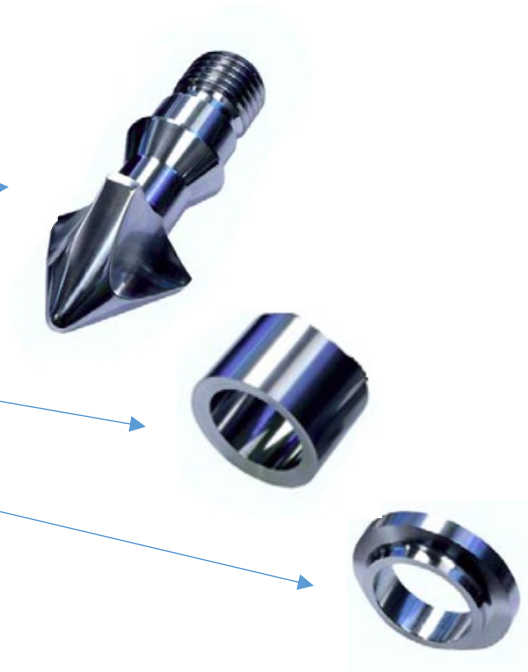
CHECK VALVE – RING VALVE

The tip of a screw is divided in to three parts:

1. **SCREW TIP**
2. **CHECK RING**
3. **SPACER**



The purpose of the valve is to:

- Allow the material to flow into the accumulation chamber during the dosing phase
- Prevent the back in of the dosed material during the injection phase

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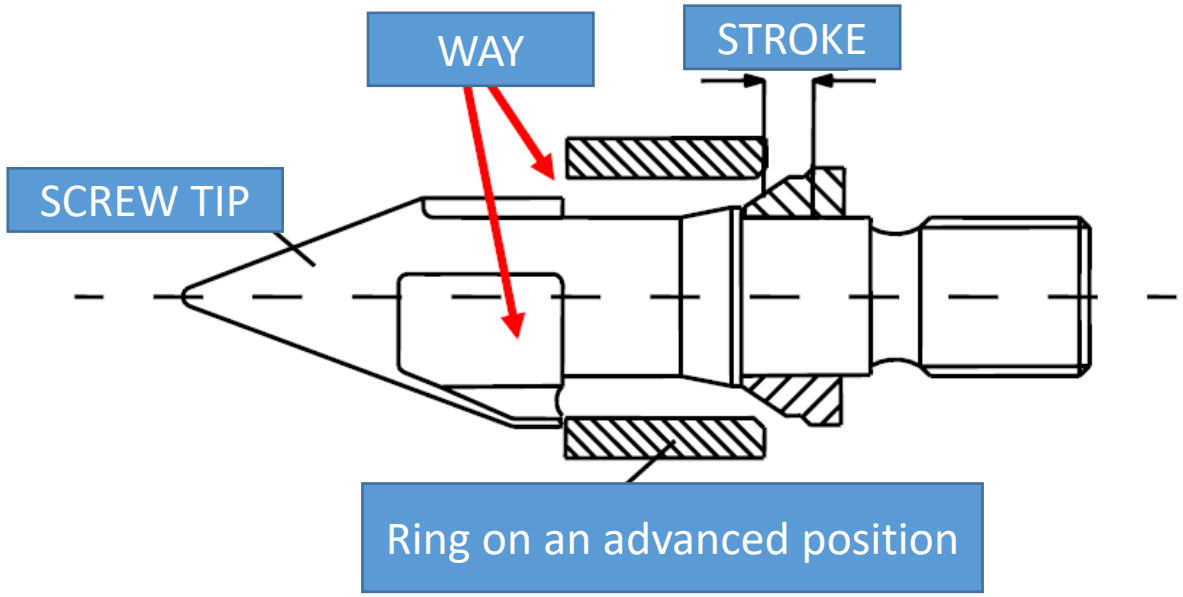
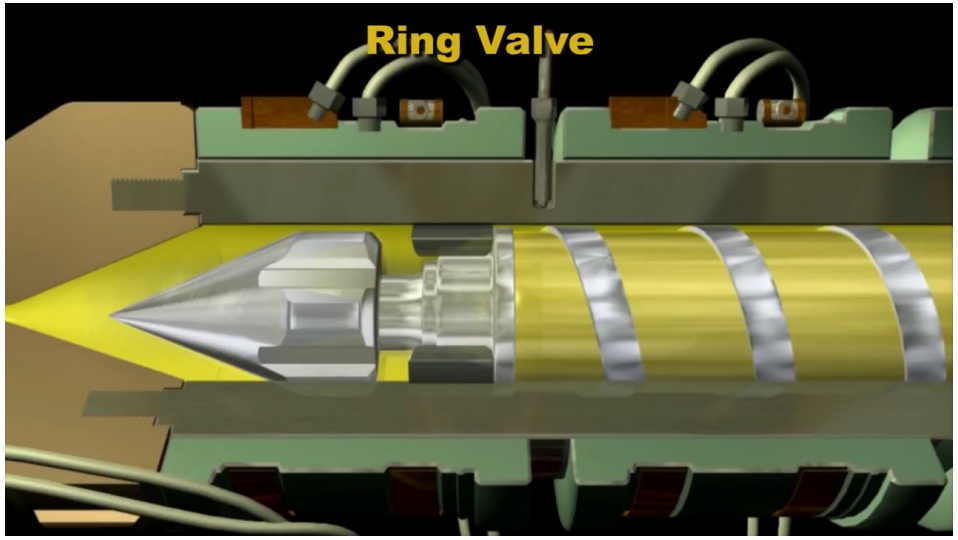
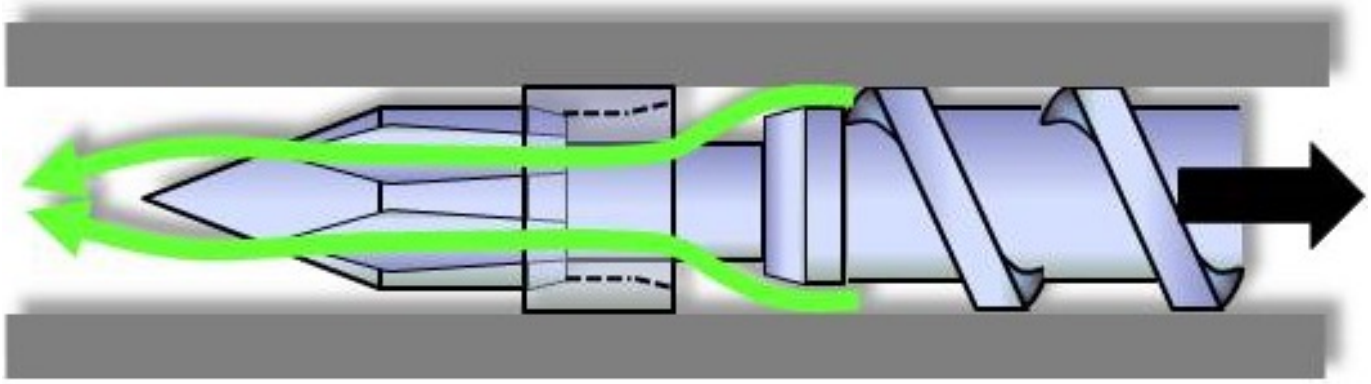
RING VALVE - dosing position







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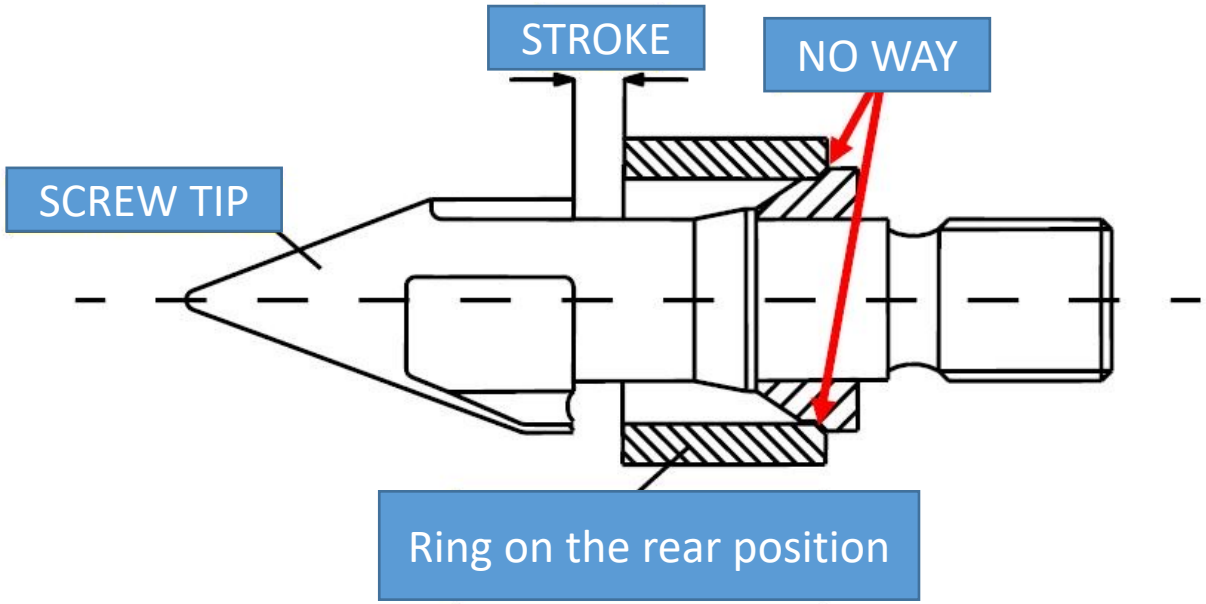
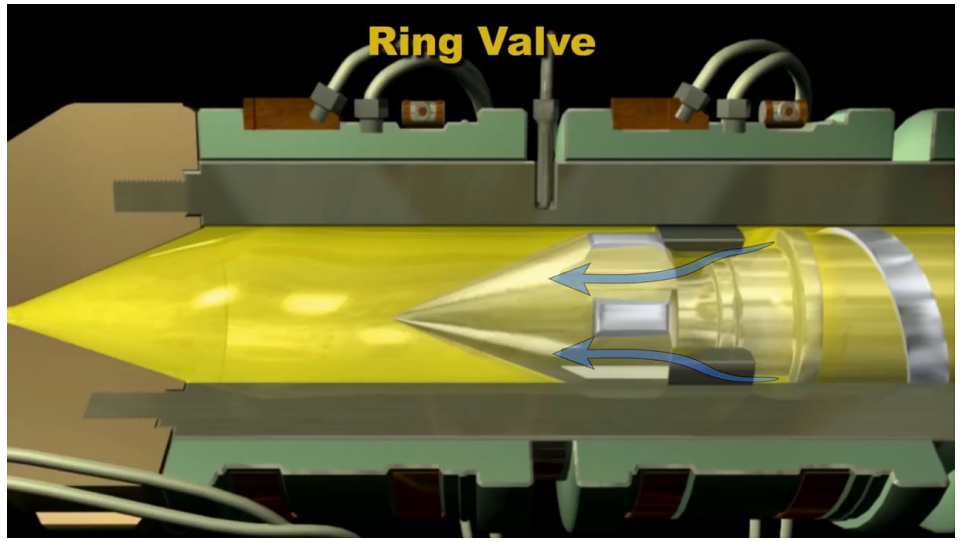
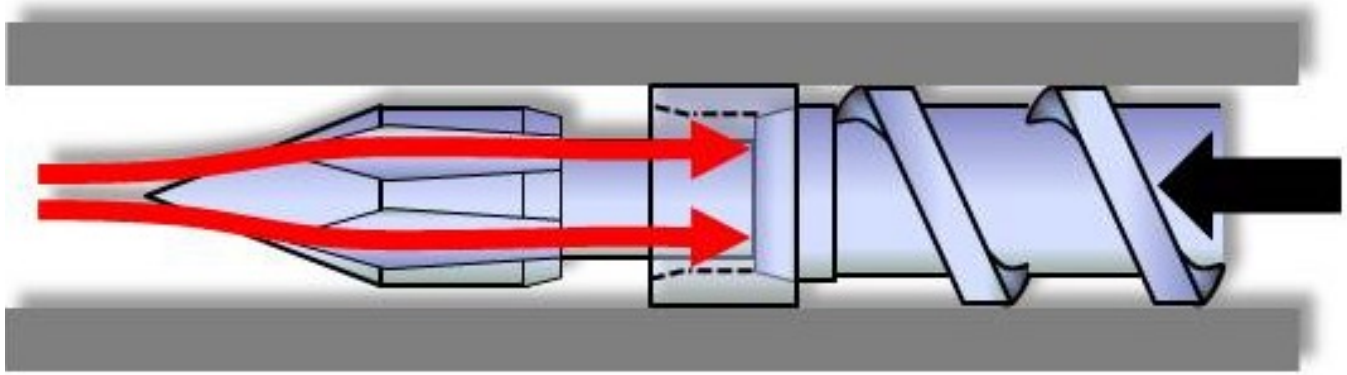
RING VALVE - injection position







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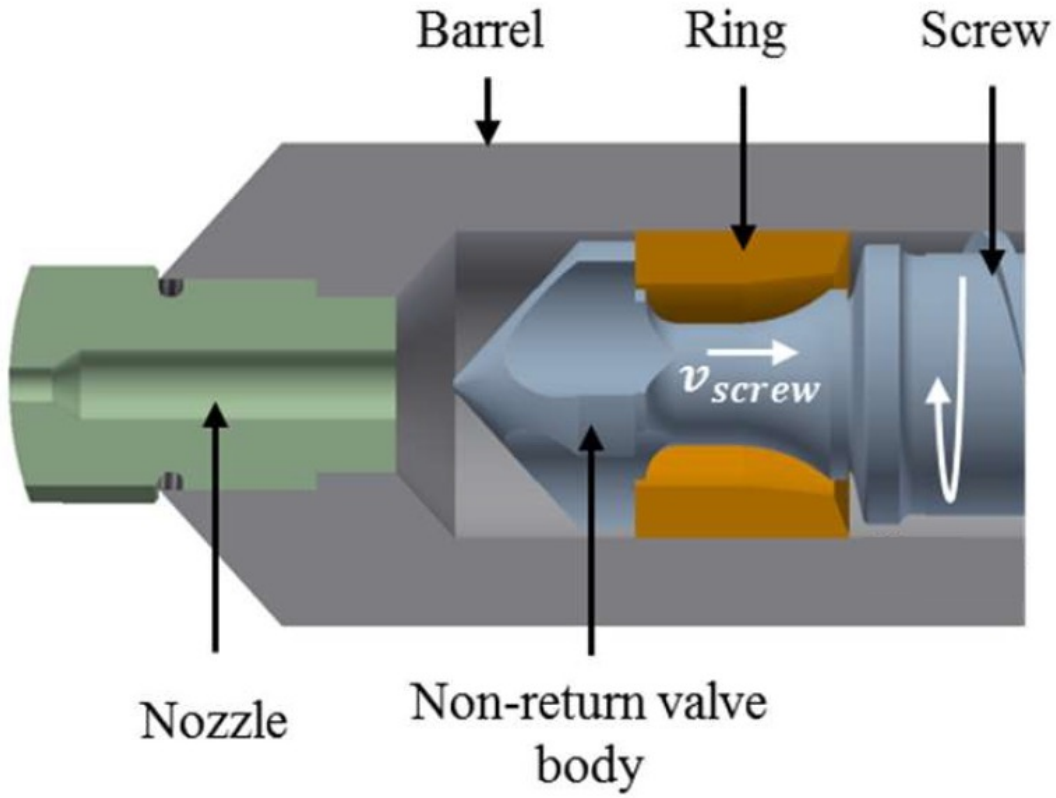
NOZZLE

Nozzle is the front part of the barrel of injection molding machine, it is the necessary and important of injection machine.



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NOZZLE – Function

1. While injection machine doing charging, establish back-pressure, drive out the air, prevent melt material flow out, and improve the plasticizing ability and measurement accuracy.
2. During injection, touch the main sprue of the mold and keep good connection and form close passage to prevent the melt material flow out under high pressure.
3. When machine do injection, help establish melt pressure, increase shear stress, also help increase shearing speed and temperature rise, enhance mixing effect and homogenization.
4. Nozzle also help the temperature regulation, heat preservation and material breakage.
5. Reduce the viscoelastic effect and eddy current lose of melt material at the inlet and outlet in order to stablize its flow.
6. While injection machine doing pressure-holding, it help feed the material into the molded product.
7. While cooling, it help increase return resistance, reduce or prevent the melt material flowing back from mold cavity.

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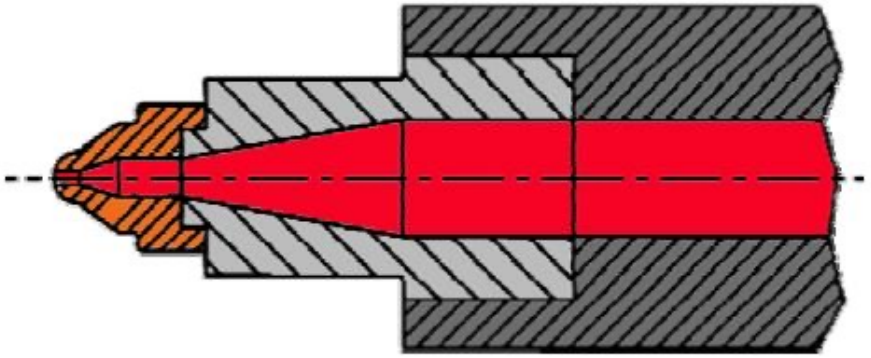
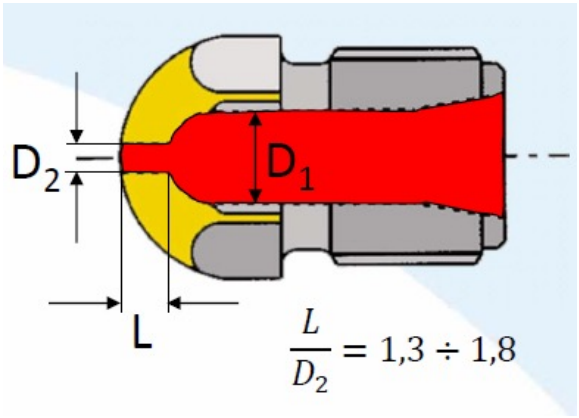
NOZZLE – Free flow nozzle

Material outlet is always open and therefore dripping of the melt is possible if has a very low viscosity.





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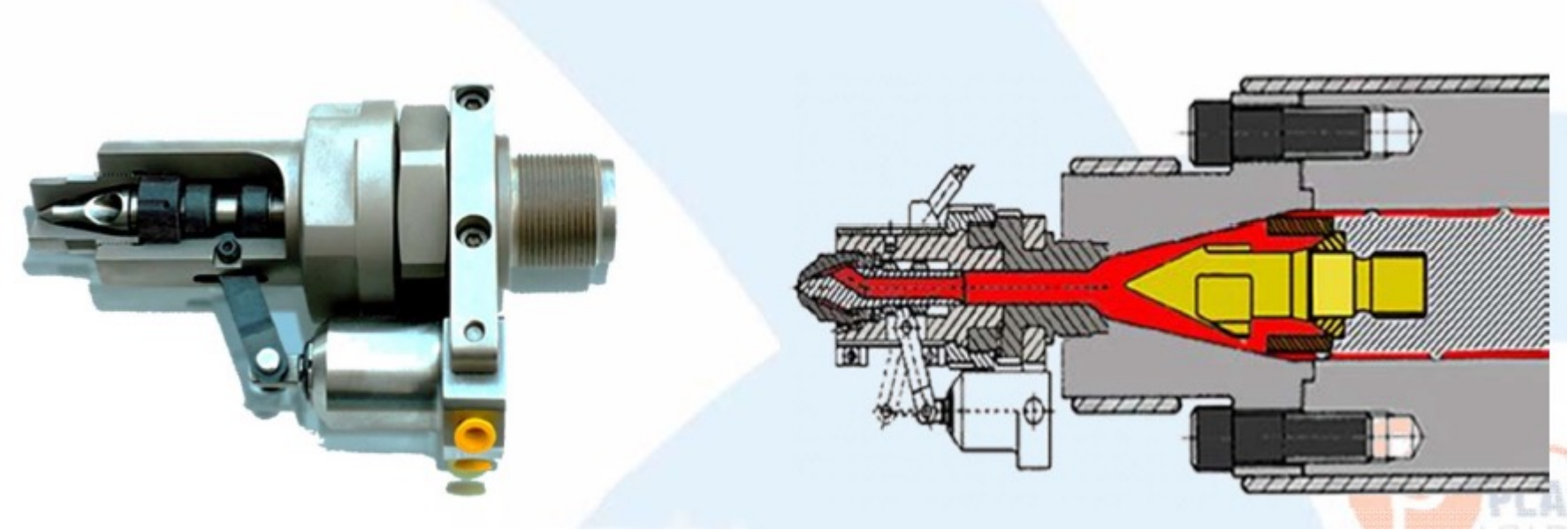
NOZZLE – Valve nozzle

The material outlet is regulated by a needle valve driven by a pneumatic or hydraulic piston controlled by a control unit.



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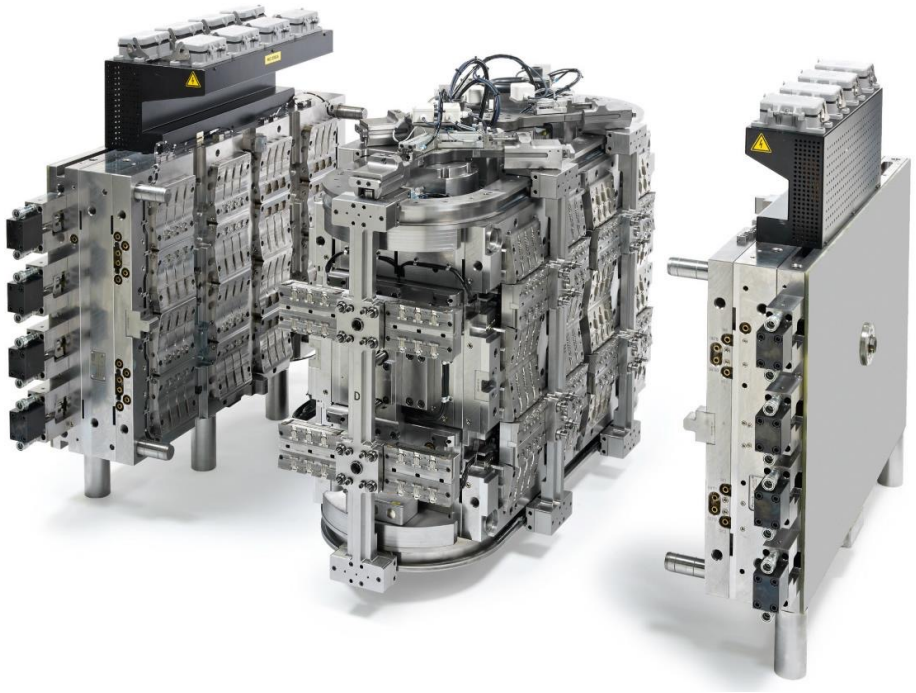
The mold

Is that equipment used in many production sectors to produce a large number of identical pieces



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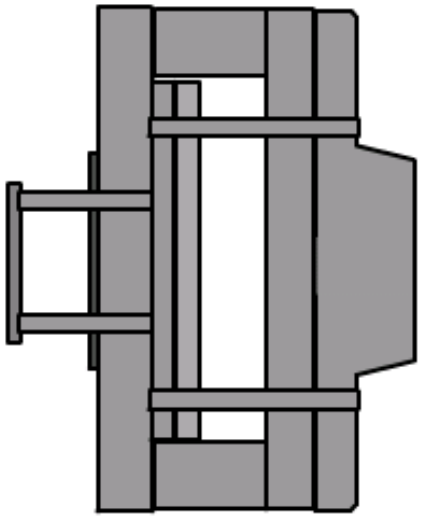
The mold

The injection mold basically consists of two parts (or half-molds), a **FIXED part** (inside there's the cavity) locked to the stationary platen and a **MOBILE part** (inside there's the core) fixed to the moving platen who containing the ejection device.



MOBILE PART

FIXED PART

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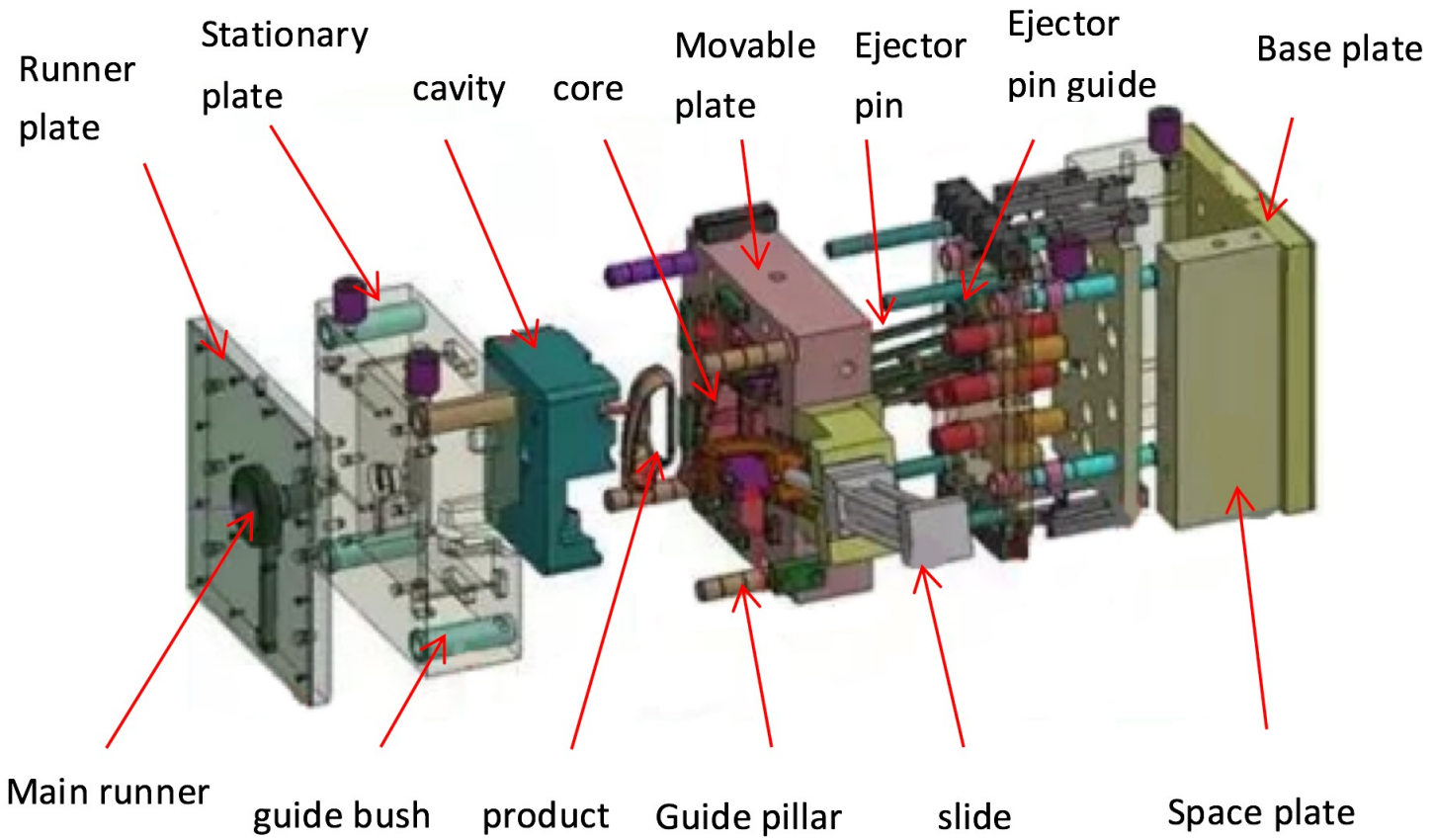
The mold



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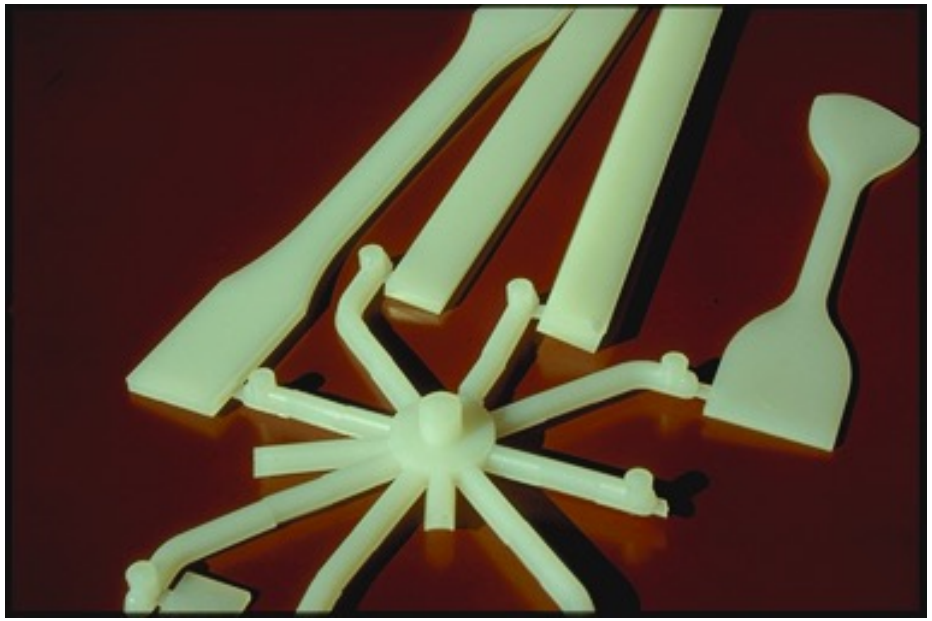
The mold – Runners

When we have more than one molded part in a mold we must use a feeding system



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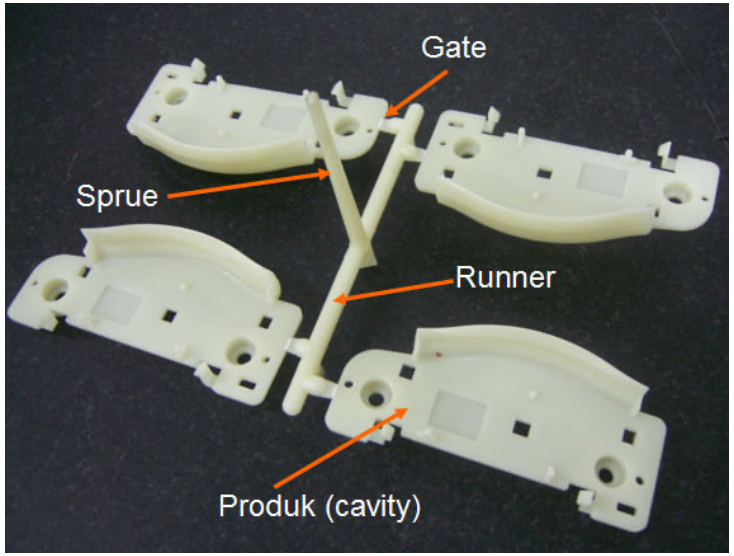
The mold – Feeding system

A feeding system in an injection mold consists mainly of:

- **NOZZLE** (which is the terminal part of the injection unit)

- **SPRUE**
- **RUNNER**
- **GATE**



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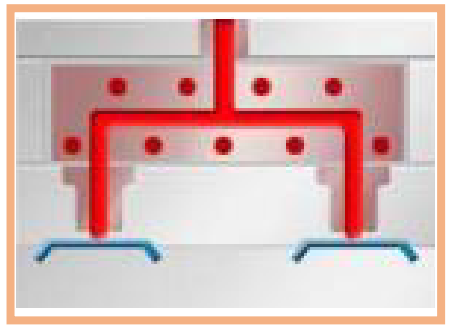
The mold – Cold Runner and Hot Runner

COLD RUNNER

- ✓ **Advantages**: constructive simplicity
- ✓ **Disadvantages**: the material present in the canal must be removed to each cycle

HOT RUNNER

- ✓ **Advantages**: temperature control more precise
- ✓ **Disadvantages**: higher cost and difficult design



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The mold – Hot runner mold

The class includes molds equipped with any system suitable for total or partial elimination of sprues and runners.

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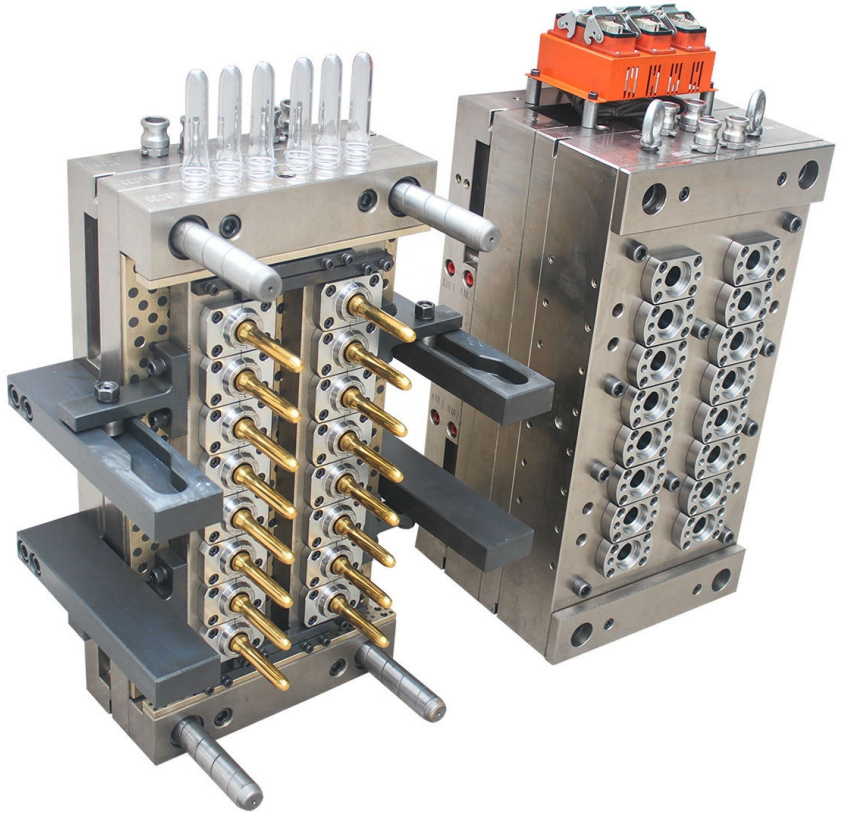
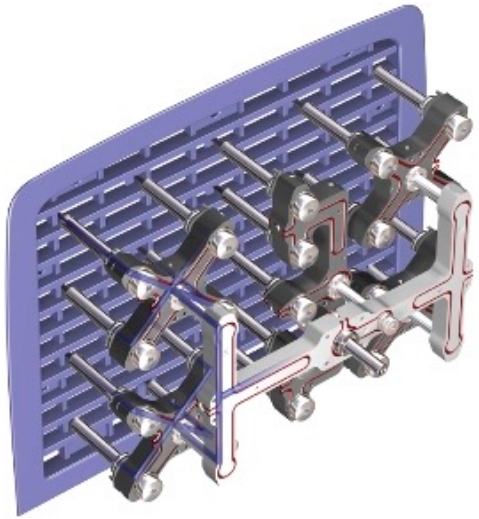
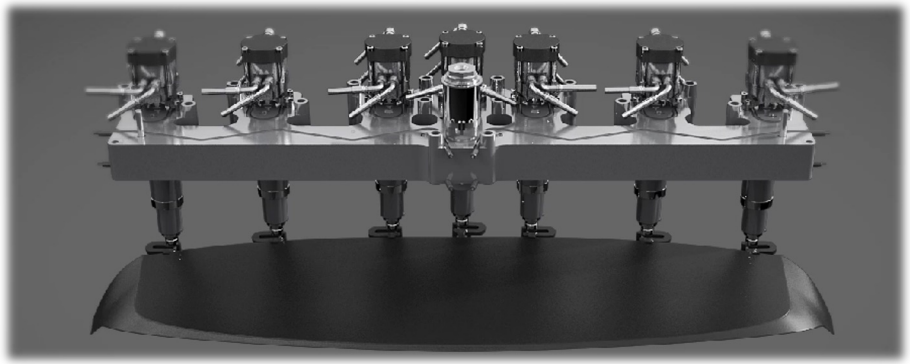
The mold – Hot runner mold

Used for multicavity molds or large item like car bumper.







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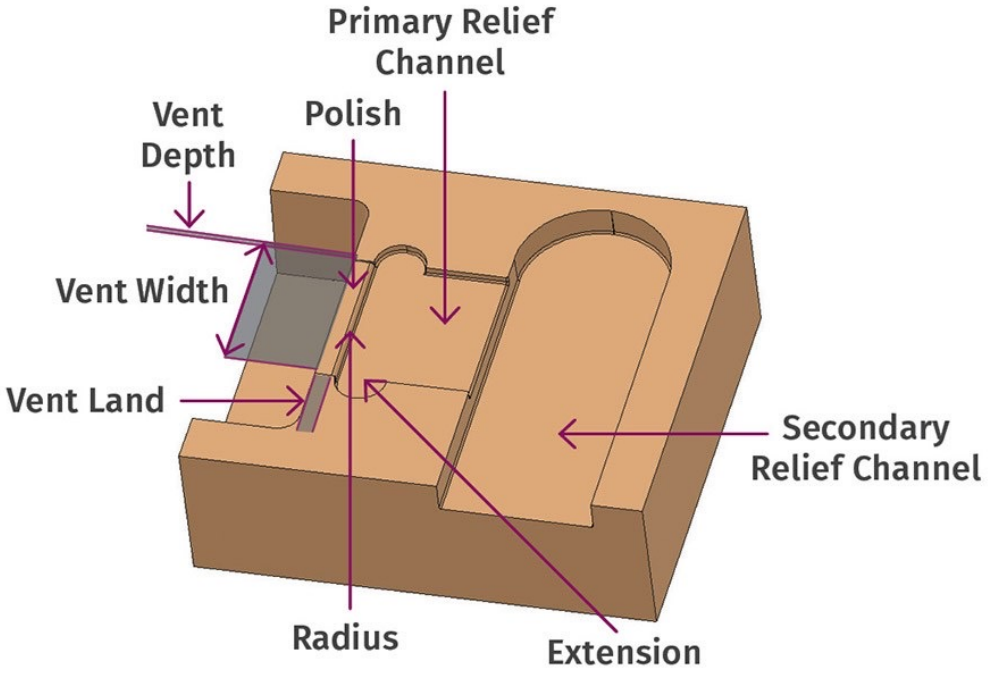
The mold - Air vents

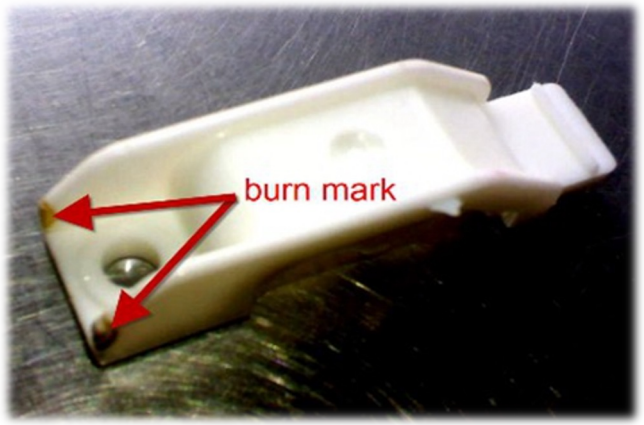
Vents are cuts within the mold steel that allows air to escape.
Air inside of the mold must be allowed to escape so that the plastic can fill the entire space.
Without vents, the trapped air will compress as the plastic tries to force the air out of the mold and will cause burning.

Depth range:

Amorphous Polymers:
- 0.020 ÷ 0.012 mm

Semi-crystalline polymers:
- 0.012 ÷ 0.005 mm





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The mold – Ejection system

The type of ejector depends in general from the shape of the molded part .

The pressure on the surface of the molded part must be as low as possible in order to avoid deformation.

- ✓ The diameter of the extractors must be as large as possible
- ✓ Use as many extractors as possible
- ✓ The extractors must exert a uniform force on the whole molded part

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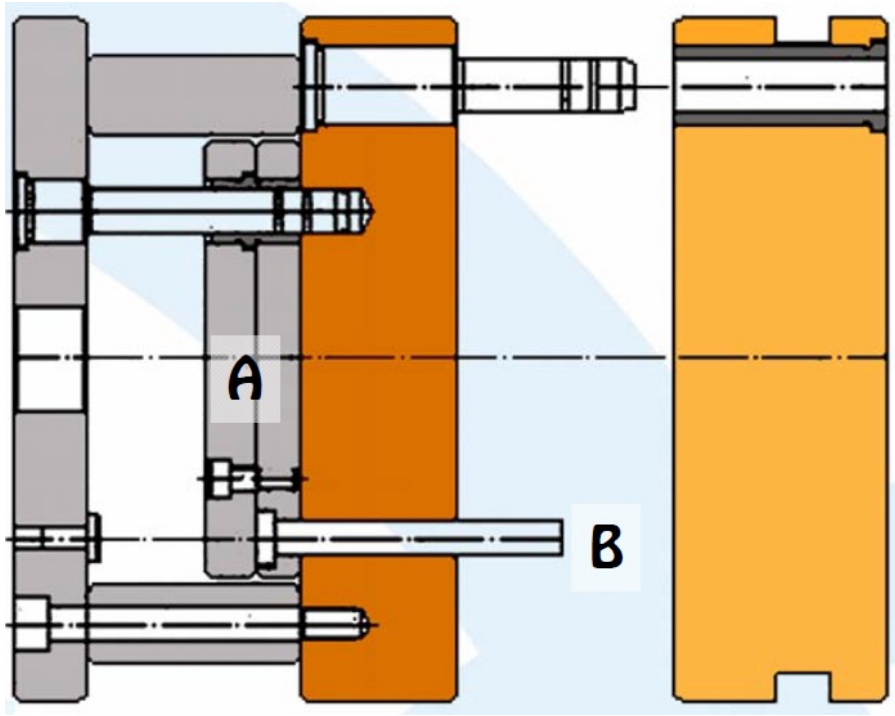
The mold – Ejector pins



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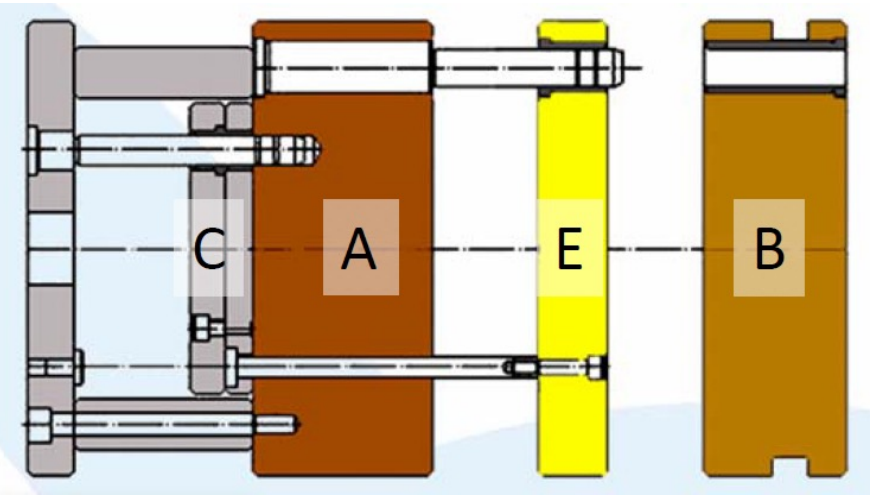
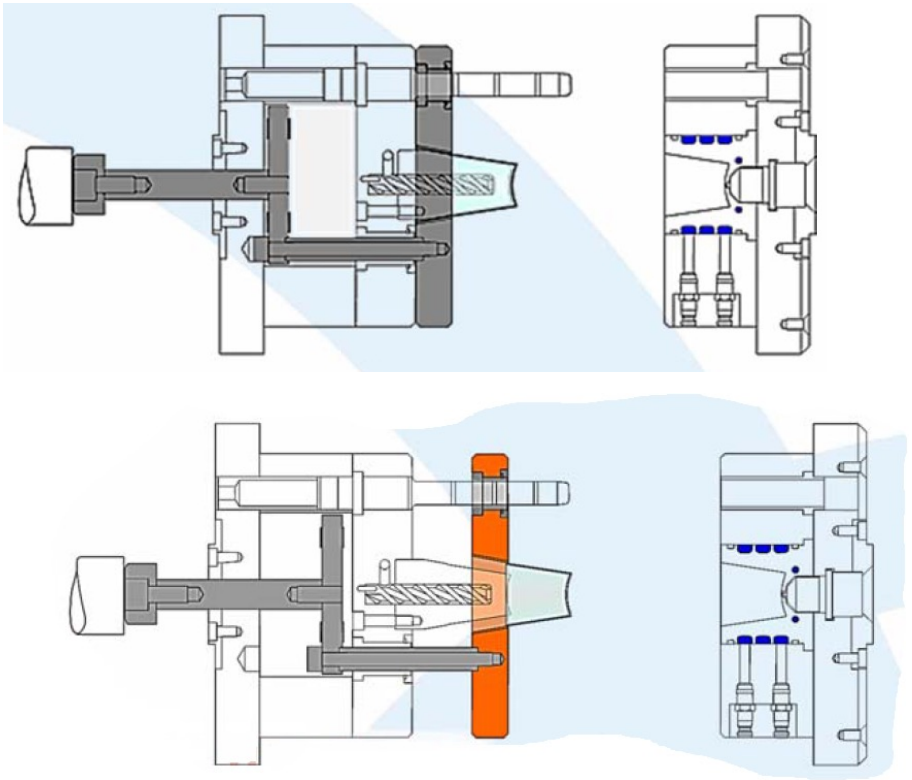
The mold – Ejector plate





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PACKALL

proplast
PLASTICS INNOVATION POLE

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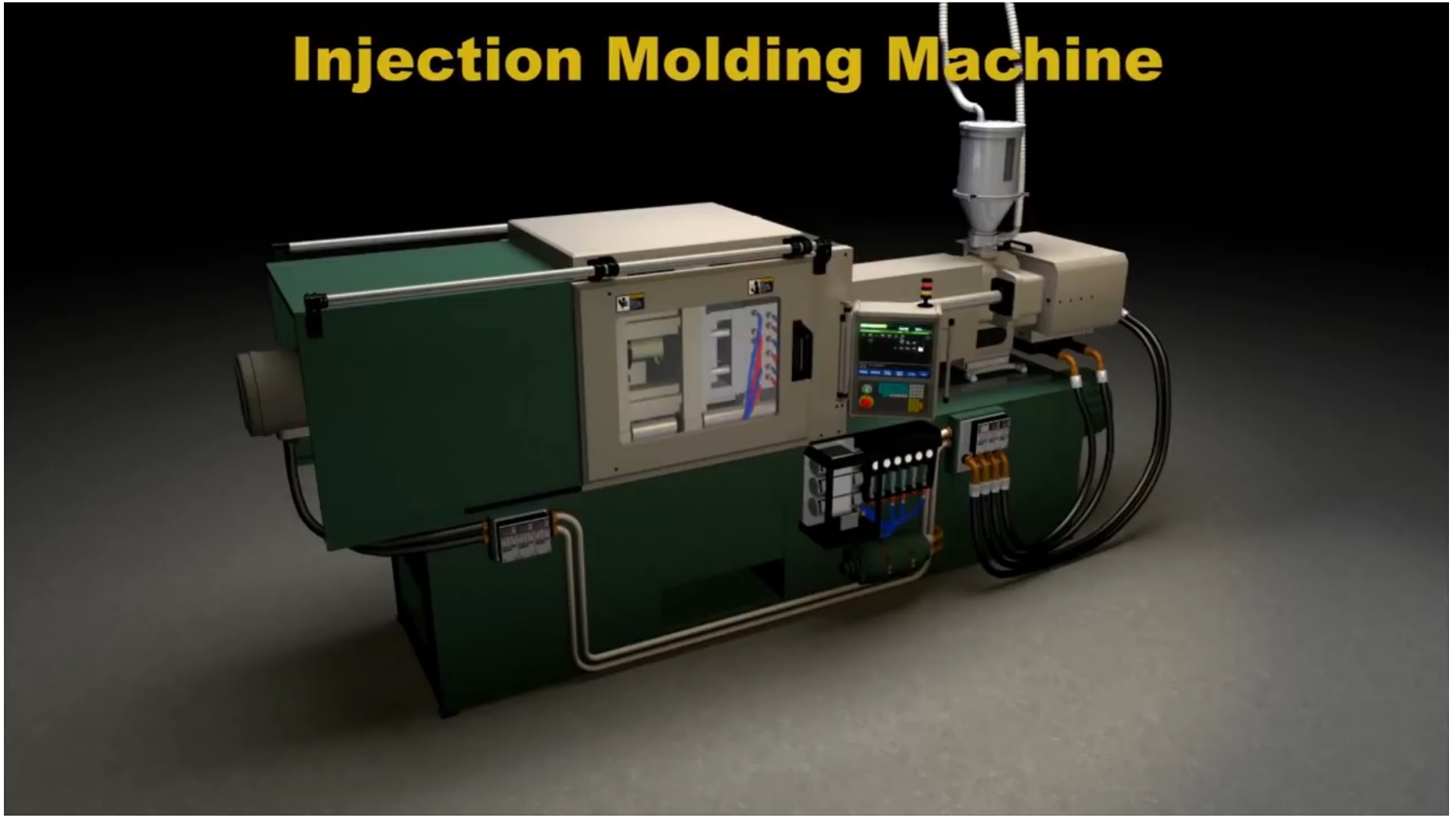
DI SALERNO



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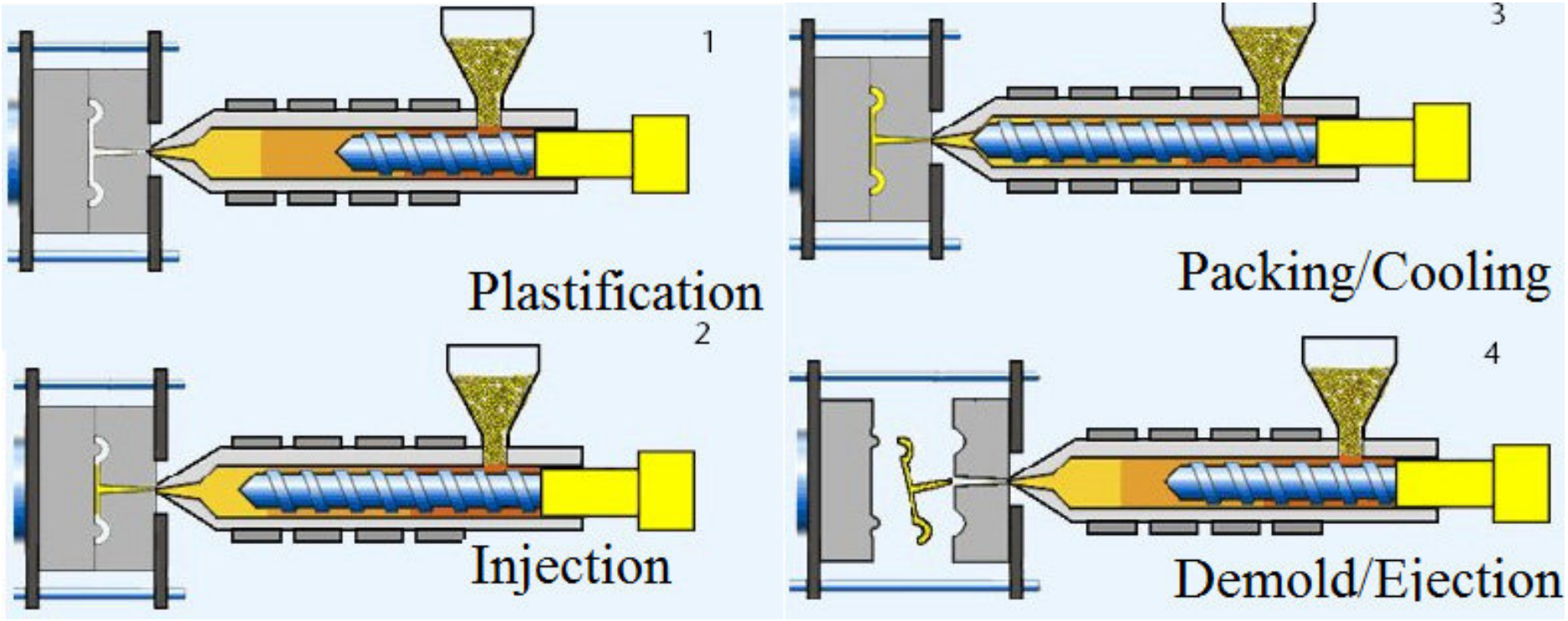
The molding cycle phases



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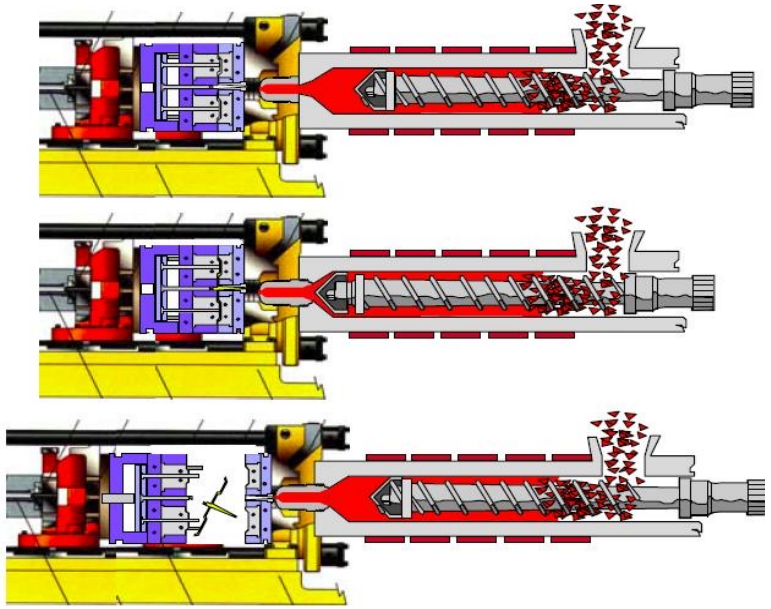
The molding cycle phases

The molding cycle is made up of some distinct phases which follow one another identical to each molded part.

The individual stages of the process are the same in chronological order, but the various percentages of contribution to obtaining the total cycle are different.

The stages of the molding cycle are :

1. Mold closing (Clamping phase)
2. Injection (Filling)
3. Packing (Holding)
4. Cooling phase + plasticization
5. Mold opening
6. Ejection stages



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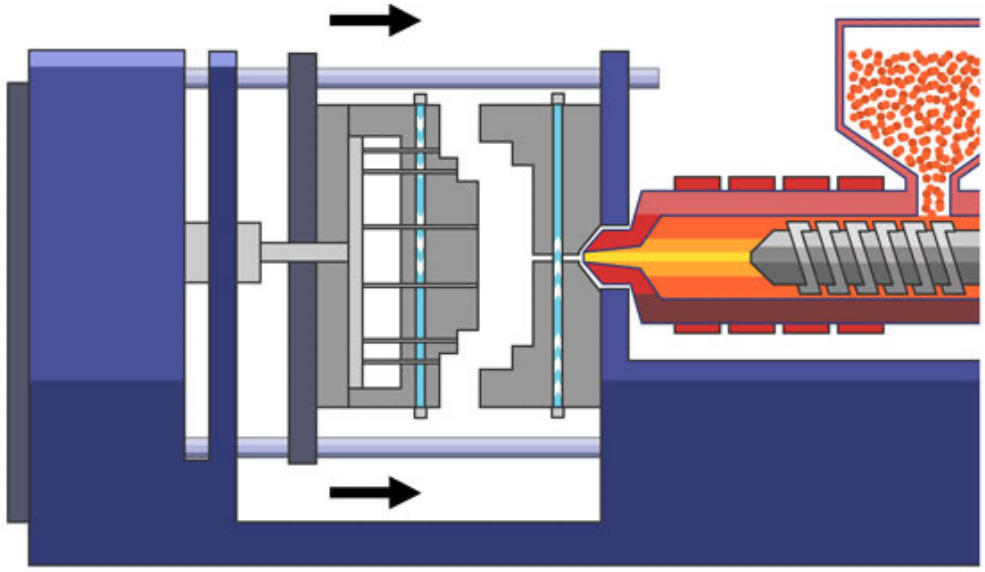
Mold closing – Clamping phase

During this phase the mold is closed and the injection molding machine develops the set closing force.

This force must be sufficient to counteract the pressure of the material



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Mold closing – Clamping phase

The clamping force, depend on the size and number of cavities of the mold and the pressure of the melt inside the cavity, allows to keep the mold closed during the molding phases.

For the right clamping force is important to know:

- Maximum length of flow in the mold
- The projected surface area of the parts in the mold
- Viscosity of the material that has been decided to use

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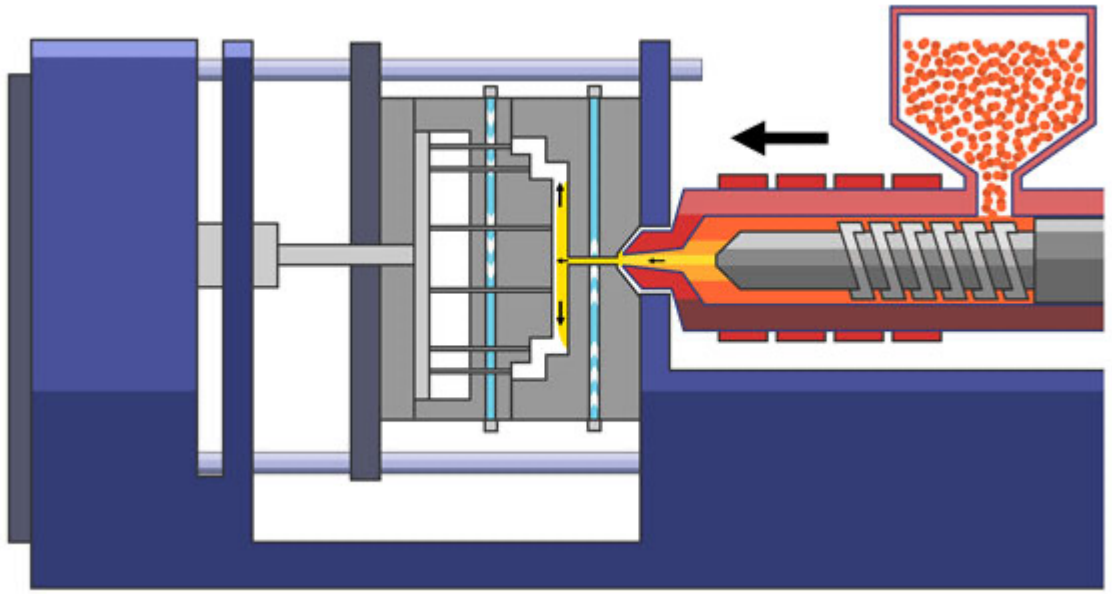
Injection - Filling

In this phase, there is the volumetric filling of the mold takes up to 98%.

The control of this phase is volumetric type: the injection molding machine regulates the speeds of the screw and, therefore, the flow rates.



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V/P Switchover

V/P switchover is the transition from the filling stage to the packing stage during injection cycle.

Various switch-over methods can be used. For example, fill-to-pack switchover can be initiated when the injection time or pressure reaches a specified value, when a specified percentage of the volume is filled, or when other conditions are met.

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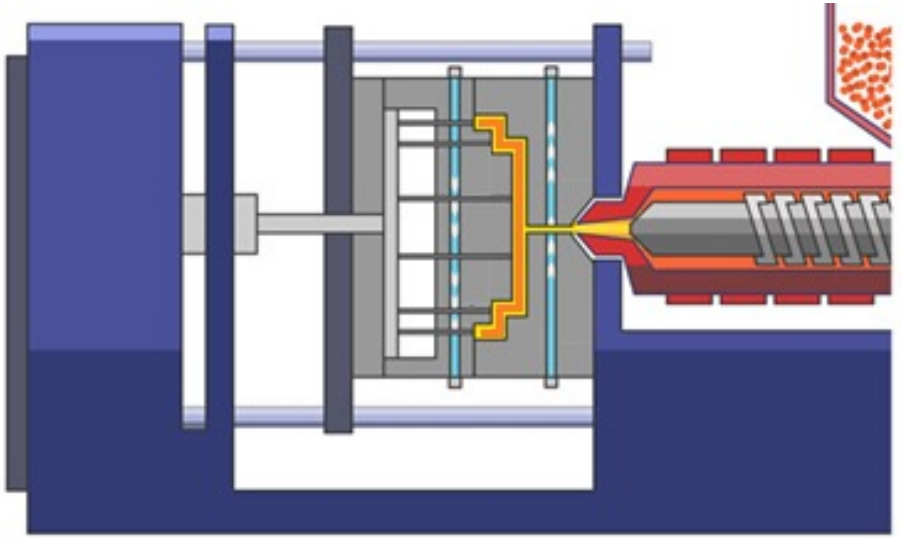
Packing - Holding

During the packing stage the pressure is adjusted, and additional material is injected into the mold to account for material shrinkage and backflow.

During the holding phase, the material is held in place at a pressure equilibrium until gate freeze occurs, at which point the cooling process begins



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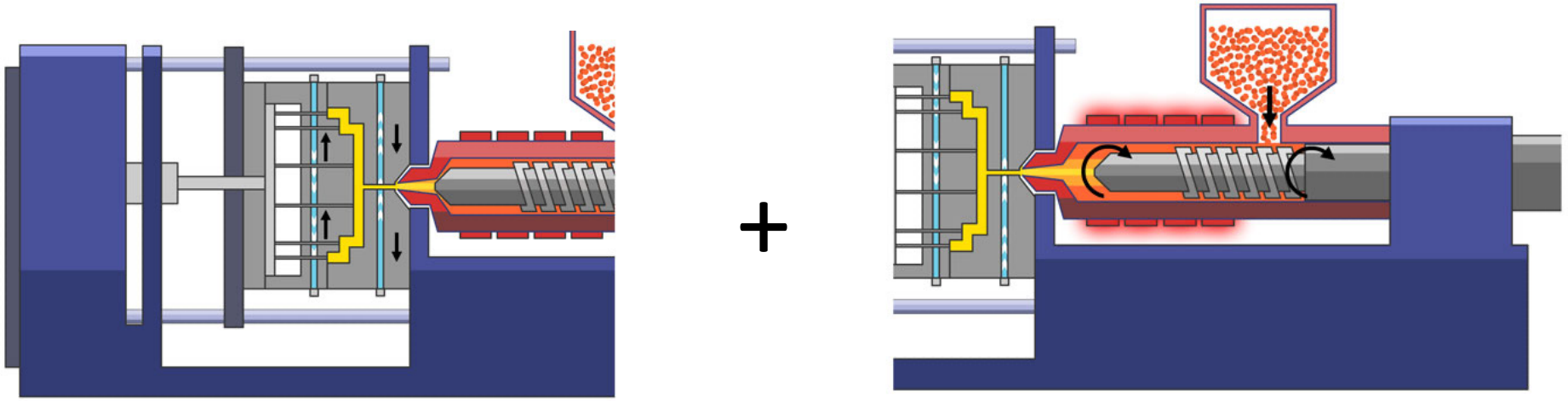
Cooling phase + plasticization

It is from the wall thickness of the part and the thermodynamic properties of the plastic that the cooling time can be estimated.

During this time the molded part must reach the typical extraction temperature of each material.

At this temperature the molded piece is structurally solid to be extracted.

This time allows the injection molding machine to carry out the plasticization.



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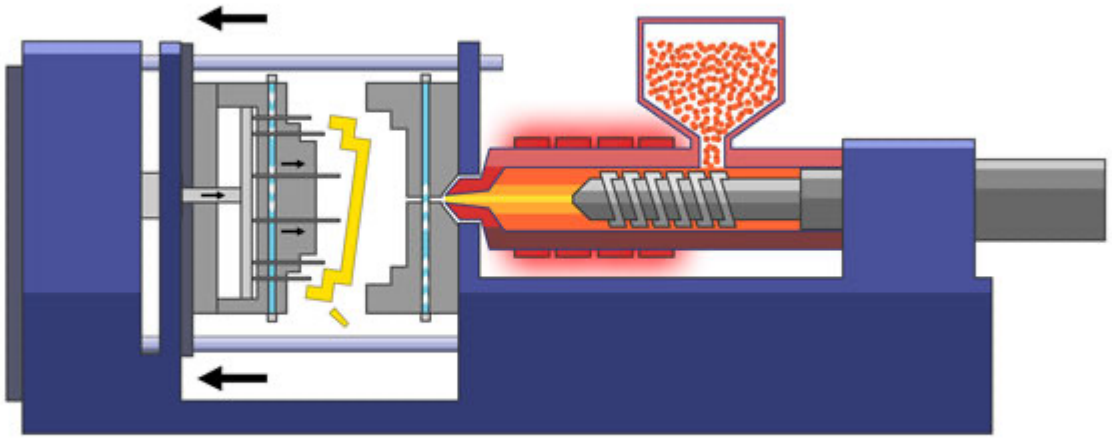
Mold opening and ejection stage

In this phase the mold opens and the ejector rod moves the ejector pins forward.

The part falls and is captured in a bin located below the mold or they are picked up by a robot.



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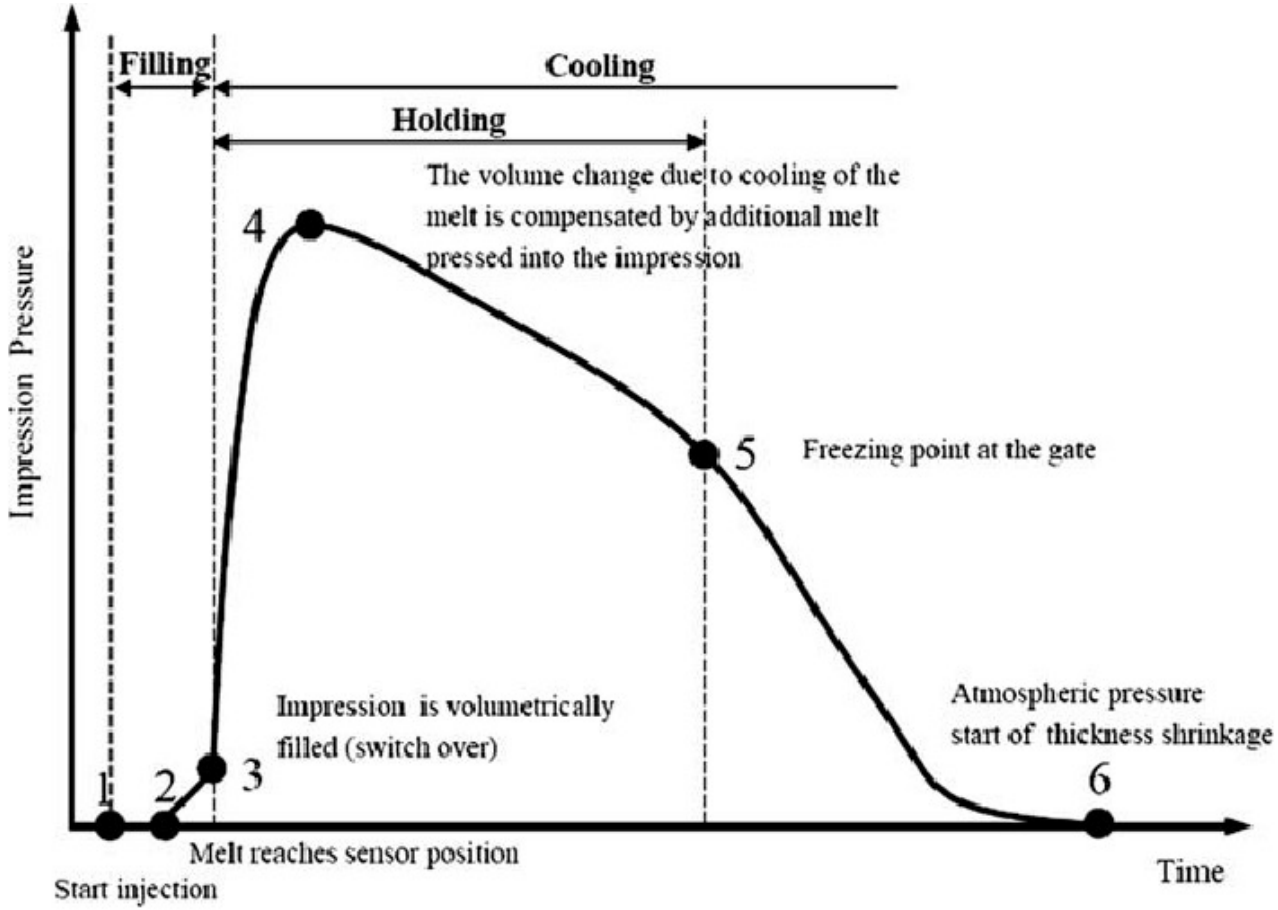
Mold cavity pressure during the cycle

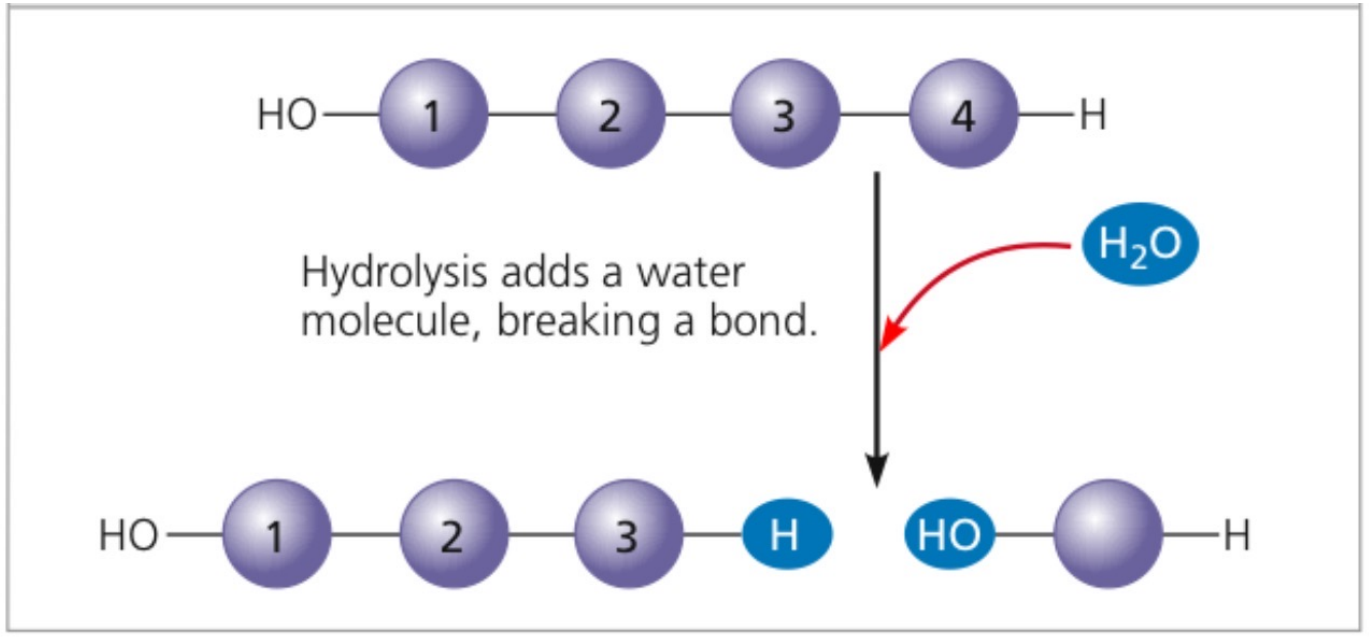


Fonte: Foam injection molding with physical blowing agents - TESI_V.Volpe

Co-funded by the Erasmus+ Programme of the European Union

Drying of Polymer

Most raw plastic material looks dry. However, everything is not always what it seems. Hygroscopic materials such as Polycarbonate, Nylon and PET to name just three, attract moisture from the surrounding air. So, although it is manufactured “dry” by the time it gets to the processor it will have some moisture content.
During processing a chemical reaction (**hydrolysis**) takes place making the long polymer chains shorter. Long polymer chains are required to make good product. Short chains result in poor quality moldings.



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Drying of Polymer

So what are the options available to plastics processors to ensure that their raw material is in the optimum condition for processing?

1) Hot Air Dryers
2) Dehumidifying Dryers

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Hot Air Dryers

Hot Air Dryers are designed to remove surface moisture from no-hygroscopic material and to pre-heat material prior to processing. This pre heating is particularly useful in circumstances where material has been stored outside in the cold and is brought into more warm and humid conditions for processing.
They usually comprise a well insulated hopper with an attached blower and heater.
Hot air is blown through the material granules and the wet air is dispelled into the atmosphere.

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Dehumidifying Dryers

Dehumidifying Dryers are designed to eliminate moisture in the plastic material before processing.
Air is forced through a desiccant bed to make it extremely dry.
This air is then heated to a specified temperature and fed into a Drying Hopper containing the material to be dried.
This hot dry air draws the moisture out of the material; the saturated air is then fed out of the Drying Hopper and back through the desiccant bed again to remove the moisture before the cycle begins again.

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Dehumidifying Dryers

Typically, plastics processors use regenerative or twin tower dryers and in this case, when the desiccant bed has reached its moisture retaining capacity the airflow is automatically switched to the second desiccant bed to allow the drying process to continue.
At the same time, the first desiccant bed is regenerated by heating to remove moisture, allowed to cool and it is then ready to absorb moisture again.

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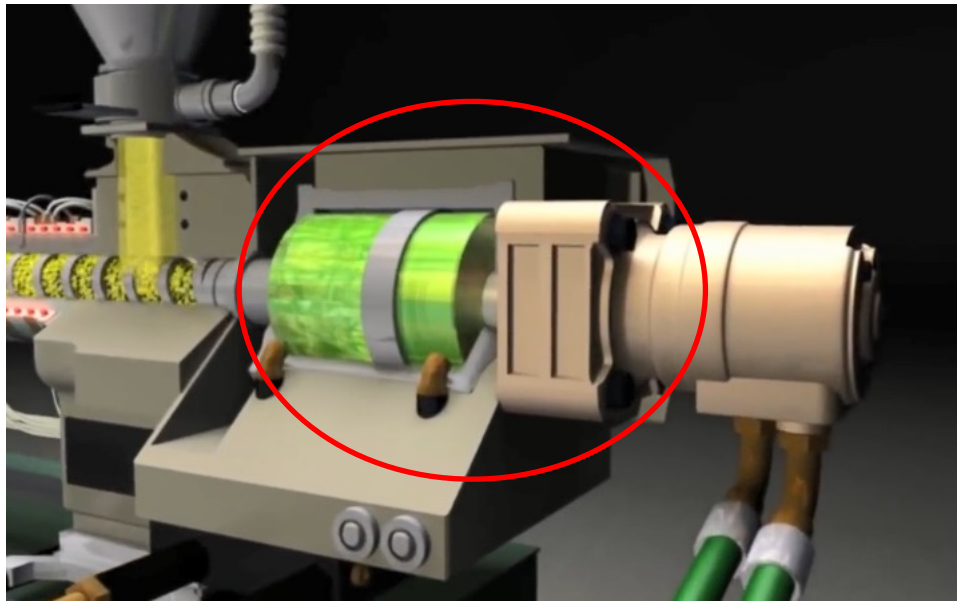
Processing parameters

Injection speed / rate is the speed of advancement of the plasticizing screw that coincides with that of the hydraulic piston with which it is integral.

The performance of an injecting unit is expressed by the injection rate (the volume of molten plastic that is injected in one second, cm^3/s) or the injection speed (the speed of forward movement of the plunger, mm/s)



Fonte: The Technology of Injection Molding 3-D Animations
https://www.youtube.com/watch?v=a8HQG2PUPik&t=74s

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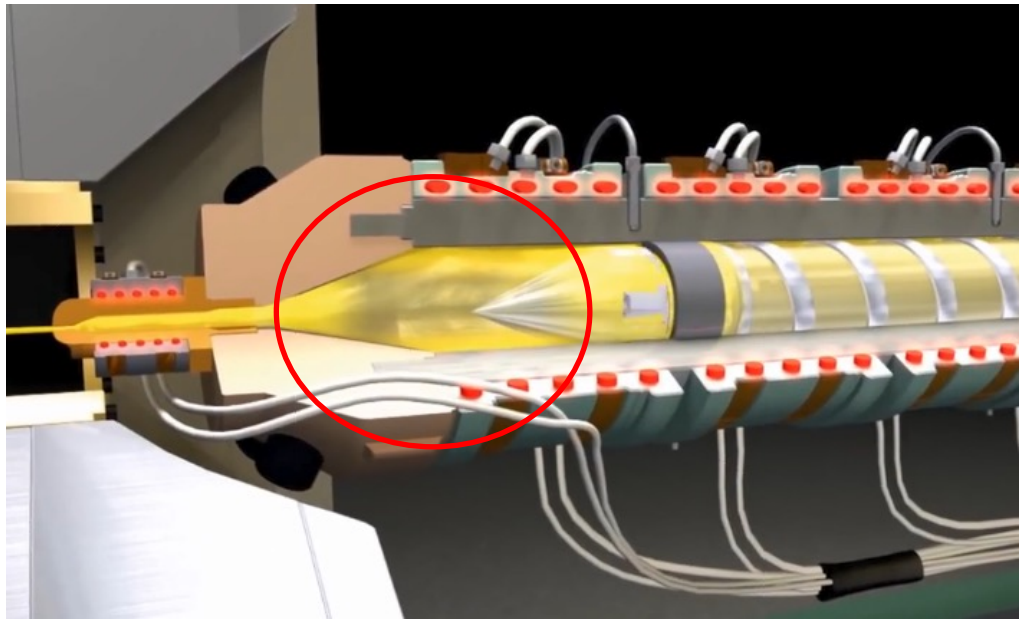
Processing parameters

Injection volume is the amount of material that is injected into the mold to adequately fill its cavity (s).



Fonte: The Technology of Injection Molding 3-D Animations
https://www.youtube.com/watch?v=a8HQG2PUPik&t=74s

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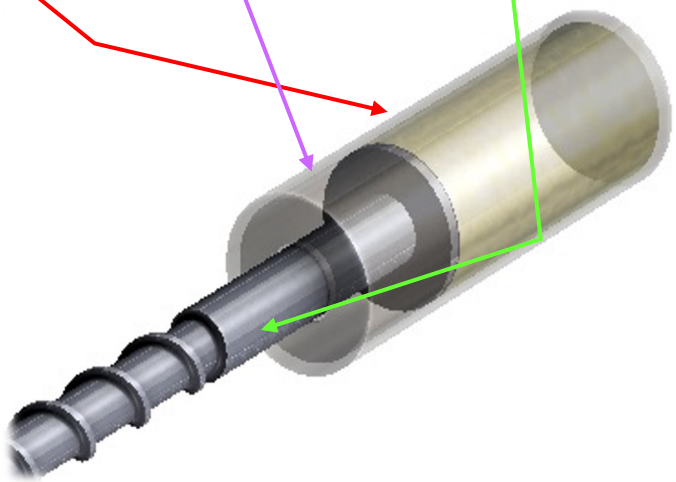
Processing parameters

Injection pressure is that pressure under which the mold fills; sometimes this is called the first-stage pressure.

It is given by the product of the oil pressure of the injection cylinder, for the ratio between the area of the same and that of the screw section - It reaches values of the order of 200 Mpa.

$$P_{max\ injection} = P_{cylinder} \times (Area_{cylinder} / Area_{screw})$$



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Processing parameters

Holding pressure is the pressure that is used to completely fill the cavity and pack out any important complex detail or texture.
sometimes this is called the second-stage pressure

Holding time is the application time until the gate freezes.

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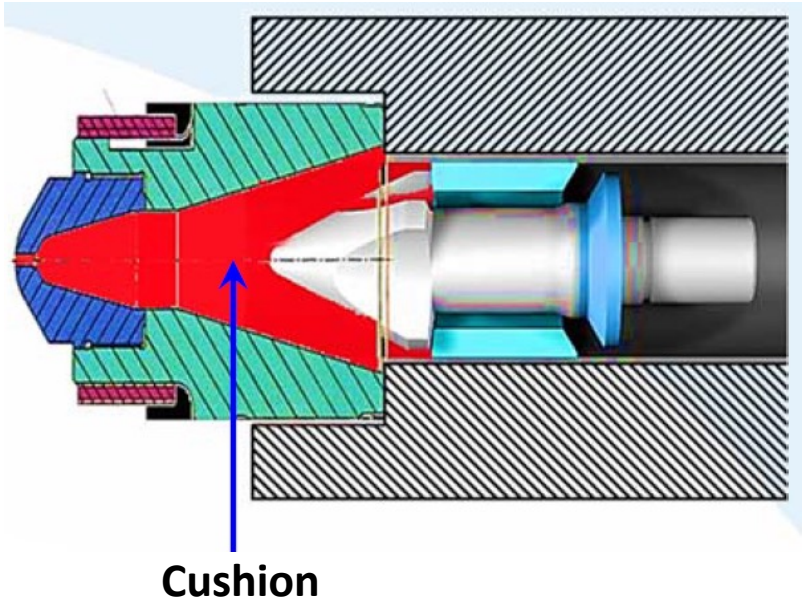
Processing parameters

Cushion is the the material remaining in the barrel, in front of the screw, after the mold filling and pack stages.

Having a cushion ensures that the screw does not bottom out against the front of the barrel, thereby preventing control of packing.



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Processing parameters

The screw rotation speed is the speed of rotations of the screw for mixing the pellets.
Its unit is rpm (revolutions per minute).

If the screw rotation speed is too high, air gets mixed inside the molten plastic which can make gas generation to occur easily.
Also, if the screw rotational speed is too low, sufficient kneading will not be made and the material quality can fluctuate.

Back Pressure in an injection molding process is often defined as “the resistance of the screw to recover as the metering section pumps molten plastic through the non-return valve to the front of the screw.” The pressure that is built up in front of the screw forces the screw back to the desired set-point.

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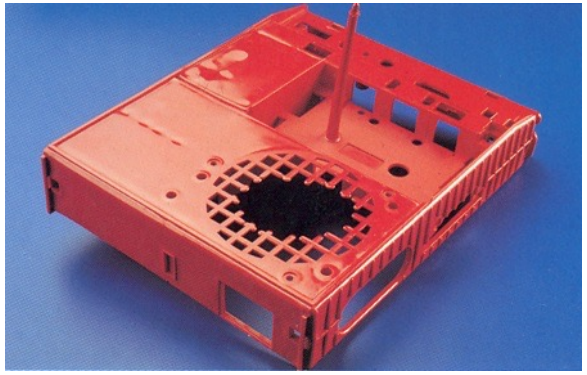
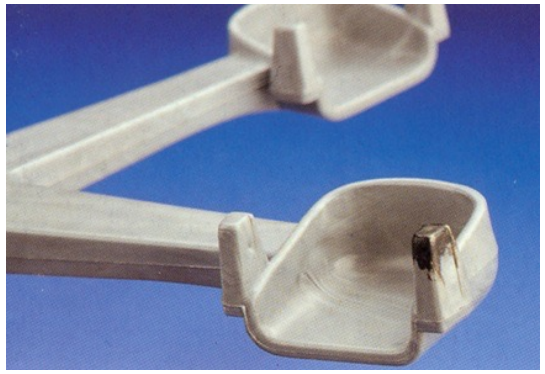
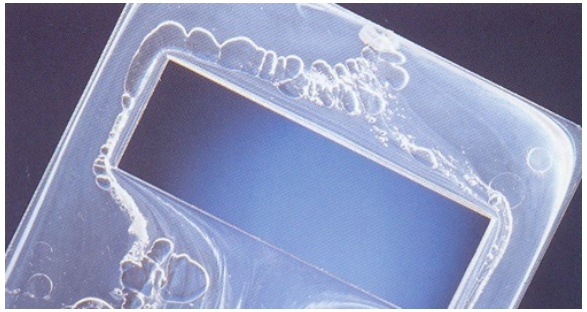
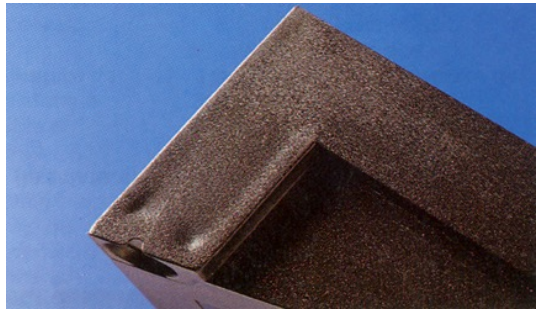
Properties and defect analysis of injected items


Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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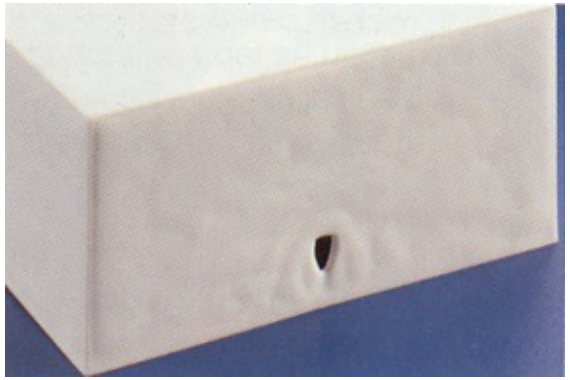
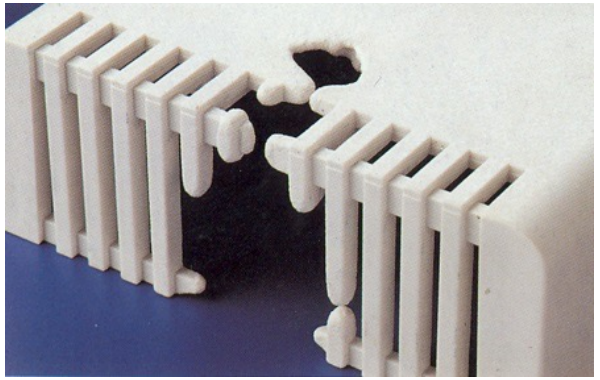
INCOMPLETE ITEM

The defect occurs at the opposite end of the injection gate or near thin walls.

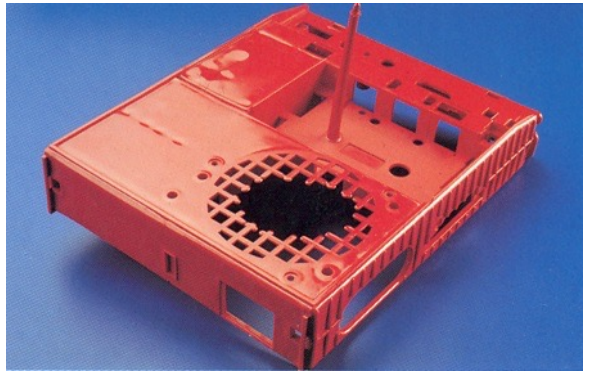
It can sometimes be caused by the inefficiency (or total absence) of air vents and therefore localize in other areas of the particular



Inclusion of air



Incomplete cause glass fiber



Incomplete on grid

Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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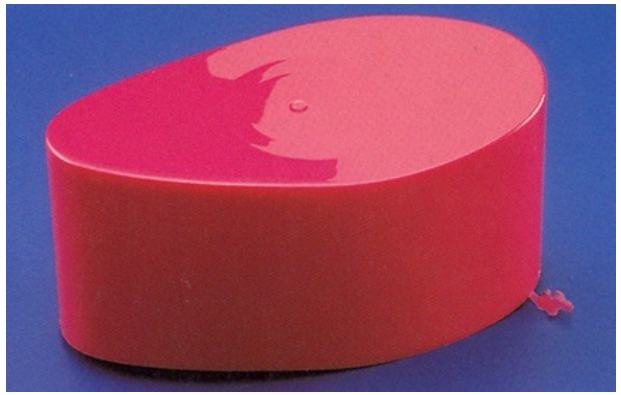
ITEM WITH BURRS

The defect occurs mainly along the division of the mold or in correspondence with the extractors or air vents.

The burrs can of course be more or less noticeable



burrs on air vent

burrs on the mold division

Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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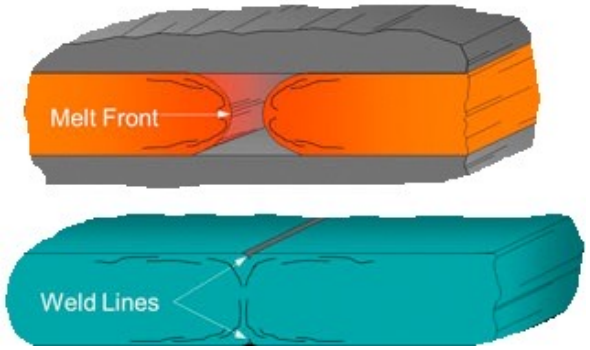
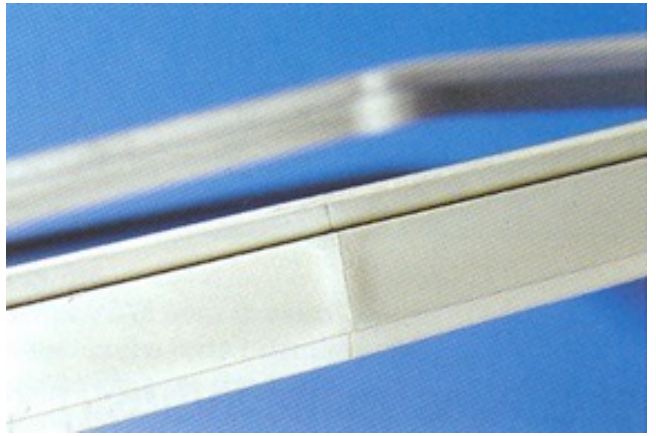
WELD LINES

The weld lines involve an aesthetic defect associated with a local loss of mechanical properties.
They are highly visible on transparent, highly colored products and on polymers with pigments with a metallic effect.





Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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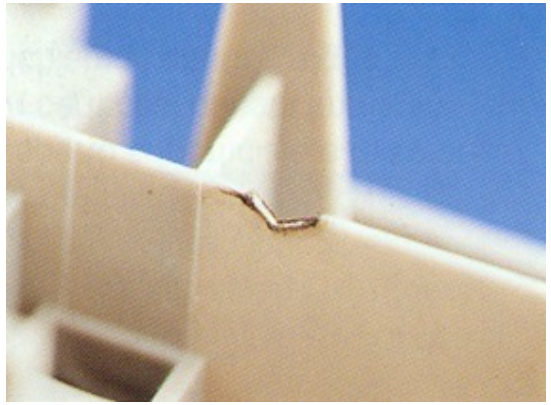
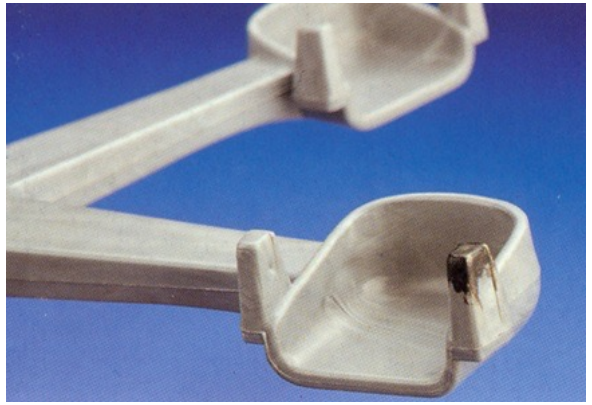
BURN MARK

A defect that appears as a brown or black mark on the surface of a plastic part.
A burn mark can be caused by an unvented air trap, which occurs when the trapped air is heated very quickly during compression and the surrounding plastic is burned.
Ram speed profiling, which gives air more time to escape from the mold, is often used to prevent this problem.





Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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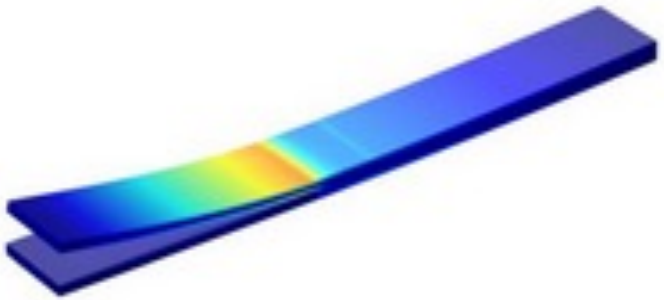
DELAMINATION

A localized separation of the part surface.
The most common cause of delamination is excessive injection velocity.



Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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JETTING

The snake-like stream of polymer melt that occurs when the melt is pushed at a high velocity through restrictive areas such as the nozzle, runner, or gate, into open, thicker areas, without forming contact with the mold wall.
In the jet, contact points form between the folds of melt, creating small welds. Jetting can lead to part weakness, surface blemishes, and internal defects.

Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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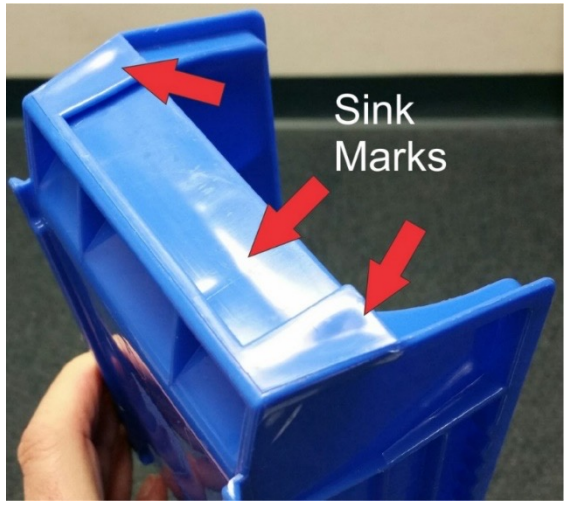
SINK MARK

A visual defect on the surface of a molded part.
Sink marks are caused by a differential in volumetric shrinkage. They typically occur on the opposite sides of surfaces to which ribs or bosses are attached, and in significantly thicker areas of parts where the volumetric shrinkage is not adequately compensated during the packing phase.



Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

Fonte: https://www.immould.com/common-injection-molding-defects-and-how-to-prevent-them/

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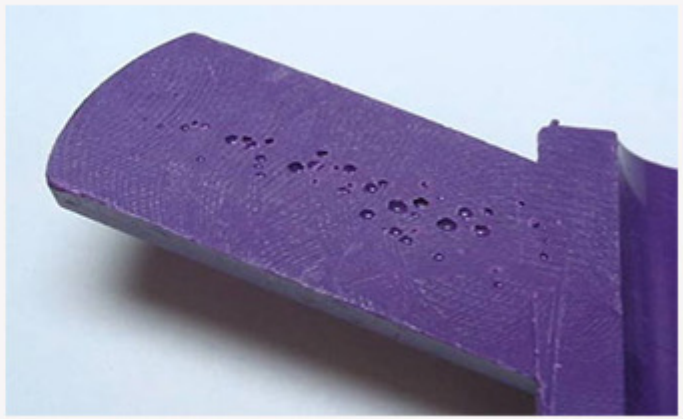
VOID

A defect in the plastic part due to the plastic pulling away from the middle of the part as the molten plastic cools.

Voids are caused by material shrinkage during the cooling phase. A void is a cosmetic defect if the part is transparent and a structural defect if the void is large.

Eliminate voids by using proper cavity pressurization in the packing phase.



Fonte: DEFECT IN PLASTIC INJECTION MOULDING PROCESS

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DEGRADATION

The defect occurs when the melt is thermally degraded due to excessive friction or due to too high transformation temperatures associated with residence times in the chamber.

Residence time too long

Friction on the gate

Fonte: https://tecnologiadelosplasticos.blogspot.com/2011/06/inyeccion-de-materiales-plasticos-ii.html

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PACKALL

PackAlliance: European alliance for innovation training & collaboration towards future packaging

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