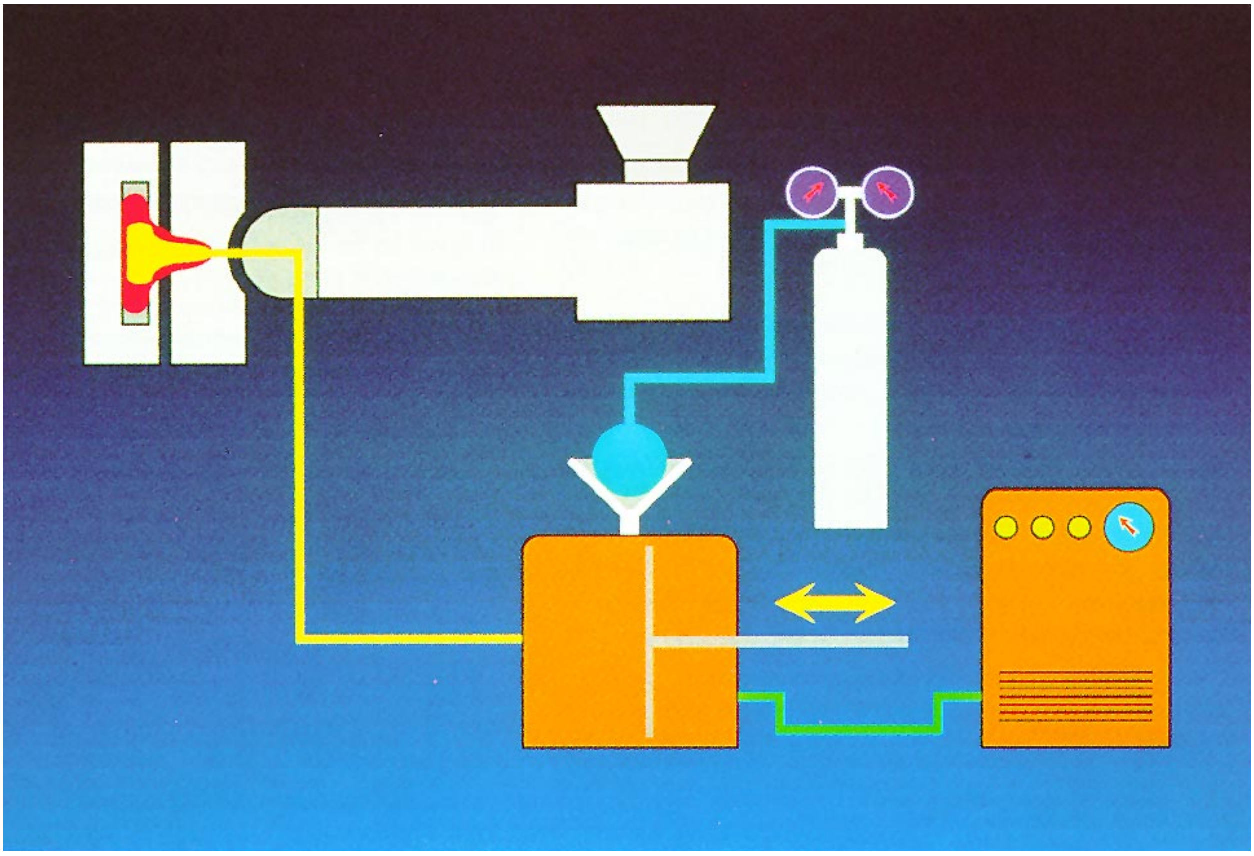
Technical Report

TRG 3060

DuPont

Engineering Polymers

Gas-Injection Moulding with DuPont engineering polymers



Start
with DuPont
Engineering Polymers

Introduction

Gas-injection moulding has been developed to save material, shorten cycle times and to improve the surface aspects of thick-walled injection-moulded parts. DuPont's European Technical Centre in Geneva has done a considerable amount of research to investigate this process' practical applications.

This technical report describes the process and its effect on materials. Special design considerations and processing recommendations are given.

General Principles

Gas-injection moulding uses a standard injection-moulding machine, extended with equipment to inject gas (normally Nitrogen) parallel or in series with the injection of the melt (Fig. 1).

Gas injection can take place through the same nozzle as the melt (machine nozzle), or via one or more special gas injection needles located at the runner or where there are material concentrations (thicker walls).

Special machine nozzle designs are needed to ensure reliability.

The gas-injection-moulding process starts with injection of plastic into the cavity (Fig. 2).

When the cavity is 50 to 95% full (depending on the shape of the part – see Fig. 3), the barrel is closed by a "shut-off" and gas injection starts. It can be controlled by pressure or by volume.

The gas expands in the cavity, pushing the plastic in front of it until the cavity is filled. Then the gas-pressure is reduced by withdrawing the injection nozzle from the sprue, so that the gas can escape. In some designs the gas may be allowed to escape from the cavity via the injection needle, so that the machine can recover the gas for re-use.

If the gas is injected through the same nozzle as the melt, a second injection of plastic is made to seal the hole in the part (Fig. 2).

Fig. 1 **Principle of gas injection unit**

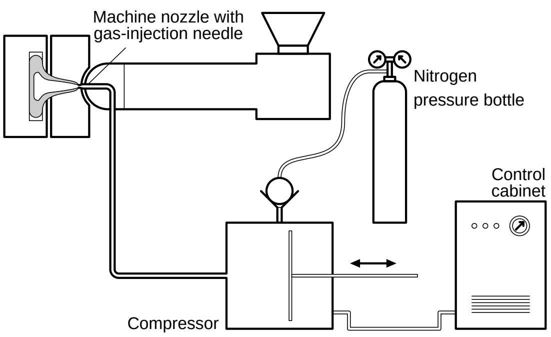


Fig. 2 **Gas-injection-Moulding Principle**

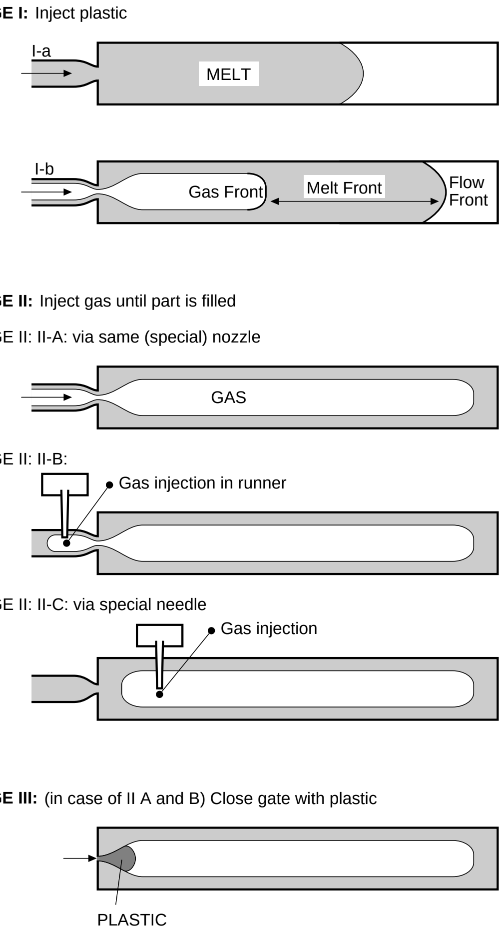
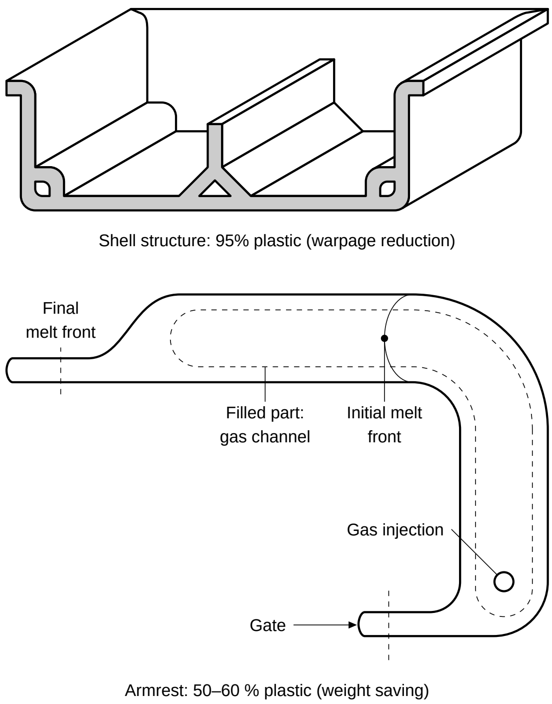


Fig. 3 **Proportion of gas to total cavity-volume for different parts**



Processing

Gas pressure

There are two important considerations relating to gas pressure:

• the time when gas injection should start (delay time)

• the gas pressure profile.

The delay time depends on the thickness of the layer frozen to the cavity wall. If the delay is too short, the gas can blow away too much material which is still liquid, leaving insufficient wall thickness. This, in addition to low melt viscosity, allows the gas to break through the melt front[1] (Fig. 4). The same phenomenon can be noted if the gas pressure is not closely controlled. The lower the resistance offered by the melt to the gas bubble, the more difficult it is to control the gas pressure. This resistance is a function of the cross-sectional area of the gas channel, the thickness of the melt front, and the melt viscosity.

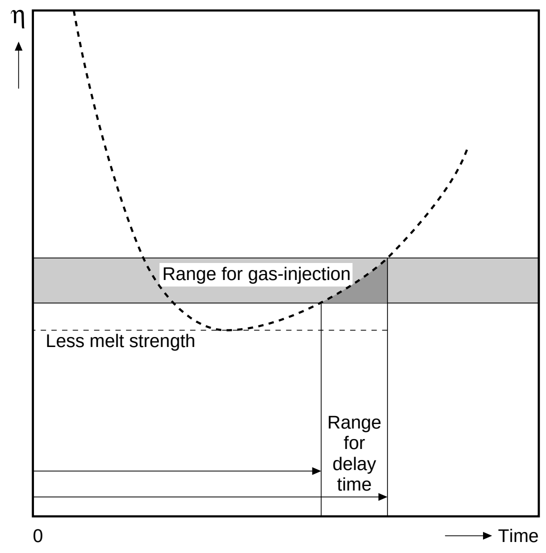
Too short a delay time may lead to turbulence in the gas and the melt; this can spoil the part's surface appearance.

The best results are obtained if, in addition to determining the correct delay time, the gas-pressure profile advances the flow front at a constant speed, so as to avoid flow marks on the surface. The melt front resistance decreases with time, because the amount of material being pushed forward by the gas is getting less. For this reason the gas pressure should be reduced as the operation proceeds, in order to keep a constant flow-front velocity. Fig. 5 illustrates this principle; however, the diagram must be adjusted according to the needs of each specific application.

When the cavity is completely filled, gas pressure can be increased again to obtain optimum crystallisation structure, better surface appearance, better packing and fewer sink marks.

Gas pressure also makes for faster crystallisation time, because it keeps the surface of the part pressed against the cavity surface, so that better cooling is obtained.

Fig. 4 **Principle dependence of delay time from melt viscosity**



Typical pressures for gas injection are 100 to 500 bar, depending on the application. To avoid turbulence during melt injection, the gas pressure level should be less than half the melt pressure in the runner.

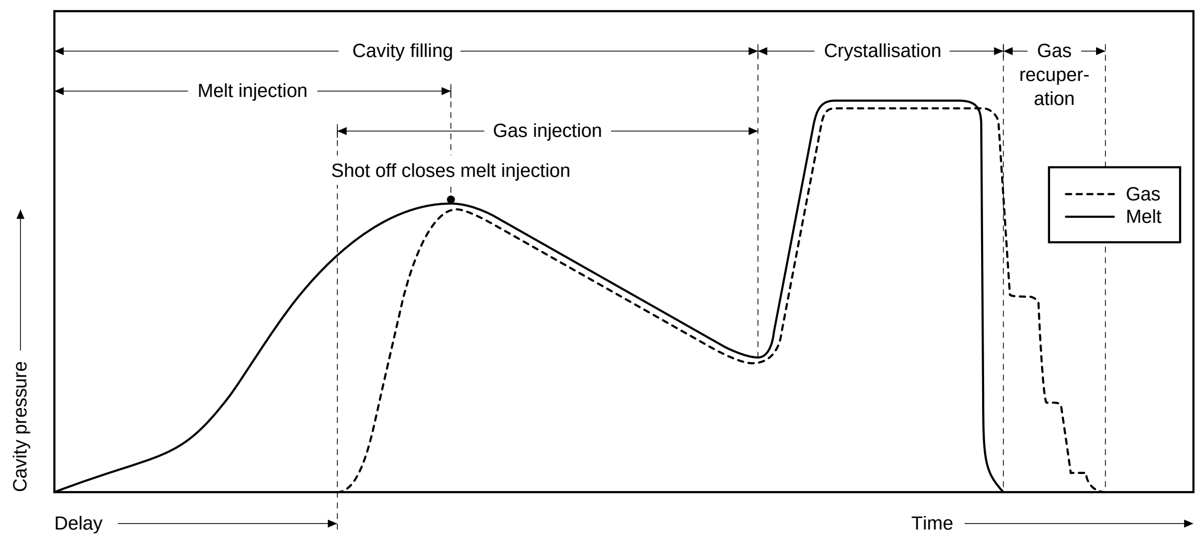
Mould temperature

Mould temperature has a direct influence of the wall thickness profile of the part. It affects the speed of crystallisation, that is to say, the rate at which the frozen skin is built up. Accurate temperature control in all parts of the mould should help to build up the desired wall thickness profile.

In general, the mould temperatures recommended by DuPont for normal injection moulding of the various resins should be observed.

[1] Terminology: The melt front is the melted plastic between the gas front and the flow front. The flow front is the cavity side of the melt front. The gas front is the contact surface between the gas and the melt front (see Fig. 2).

Fig. 5 **Pressure-diagram for constant flow front speed with gas-injection moulding**



Melt viscosity

Melt viscosity affects parts in two important ways

- size of the gas cavity
- reproducibility

Higher melt viscosity produces thicker walls, narrower and shorter gas channels with more remaining material at the end, and allows high reproducibility.

Lower melt viscosities produce longer gas channels with a larger cross-sectional area, but usually with less uniform wall thicknesses (Fig. 6). Because low melt viscosity reduces the pressure-drop between the gas front and the flow front, there is a danger of unequal melt fronts with less reproducibility, especially where there are more than one melt fronts.

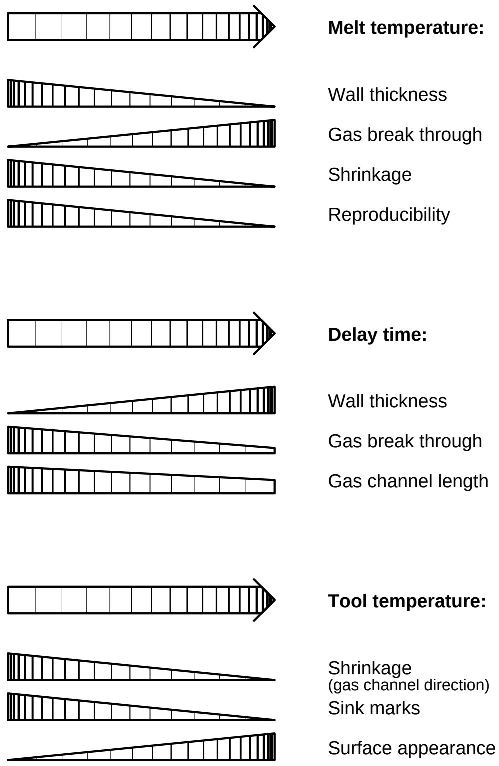
Decreasing melt viscosity has another negative influence on the process: melt strength decreases with lower melt viscosity, so that the gas can break through the melt front more readily.

Plastics with a stable viscosity over the processing temperature range will give the best results. Processing parameters of crystalline materials must therefore be set more carefully than those of amorphous materials.

Processing parameters

The influence of processing parameters on the gas injection process is shown in Fig. 7.

Fig. 7 **Influence of processing parameter**

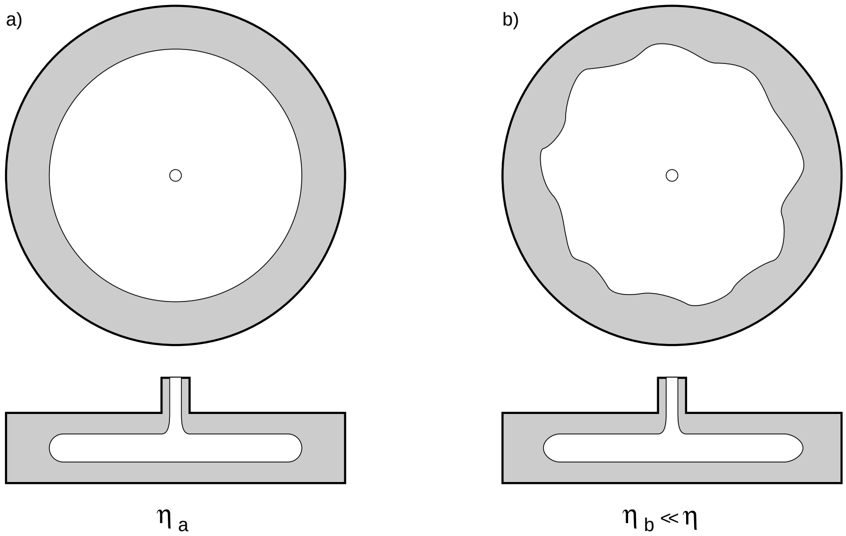


Process simulation

The complexity of gas-injection moulding requires process simulation to predict processing parameters and optimum part design if development time is to be reduced.

Process simulation software has been developed to simulate mould filling, including a phase where a second component – the gas – is injected. Results to date from use of this software, compared with data obtained experimentally, show that some basic assumptions still need to be improved.

Fig. 6 **Wall thickness depends on melt viscosity for gas-injection moulding**



Design

The best designs for gas-injection moulding are parts in which the gas flow is in one direction only – i.e. not around corners or bends.

Usually, special rules apply to parts designed for the gas-injection-moulding process. The basic rule is that the gas always pushes the plastic away at the locations with the best flow conditions – that is to say, where resistance to the melt front is lowest. For this reason, gas channels will tend to appear in sections with large cross-sectional area and/or higher melt temperatures.

This is illustrated in Fig. 8. The upper part of the illustration shows a design with a sharp corner and melt accumulation; the lower part shows an improved design with rounded corners.

The gas in the cavity fulfils two main functions:

- to produce a hollow cavity, weight reduction being the main objective.
- to provide constant pressure throughout the part in order to compensate for volume shrinkage after the cavity has been filled; the main objective is to avoid sink marks, thus obtaining a smooth surface.

For thin parts with a relatively large cross section, such as handles, weight saving is the main reason for using gas injection. Gas channels tend to be a feature of these designs.

For shallow parts with stiffening ribs, the main reason for using gas-injection moulding is the creation of a smooth surface without sink marks. Gas channels are needed for such parts to bring the gas to locations where the volume shrinkage of the material could otherwise cause a sink mark.

Since shell structures (e.g. housings) normally do not include sections which can be used as gas channels, channels have to be specially designed. This can be done at corners for the shell or at rib/shell junctions. Fig. 9 shows examples.

Ribbed housings with gas channels to avoid sink marks often need to link the ribs in a network by an incorporated gas channel which goes around the geometry of the part. Reduced warpage is an advantage of this kind of design.

The size of the gas channel depends on the volume shrinkage of the material and on the size of the shell.
The following considerations are of importance:

- the smaller its size compared to total flow length, the sooner the gas pressure has to be activated in order to avoid the gas channels freezing off. This means that the gas channel will try to compensate the volume shrinkage of the flat part, too, by pushing melt into flat, shrinking sections. A cross-section over a part with a gas channel that is too small can give results such as those shown in Fig. 10. Because of lack of melt, gas is pushed into the shell, producing "notches" which are undesirable if the part is to resist high dynamic loads.
- the larger the square section of the channel, the longer the activation of the gas pressure can be delayed. However, channels that are too big mean extra weight and a less stable melt-flow front, though they increase the stiffness.

As a rule of thumb, gas channels should be designed to be 2 to 3 times bigger than the shell thickness (Fig. 9).

Fig. 8 **Wall thicknesses in a corner without – and with rounding-off**

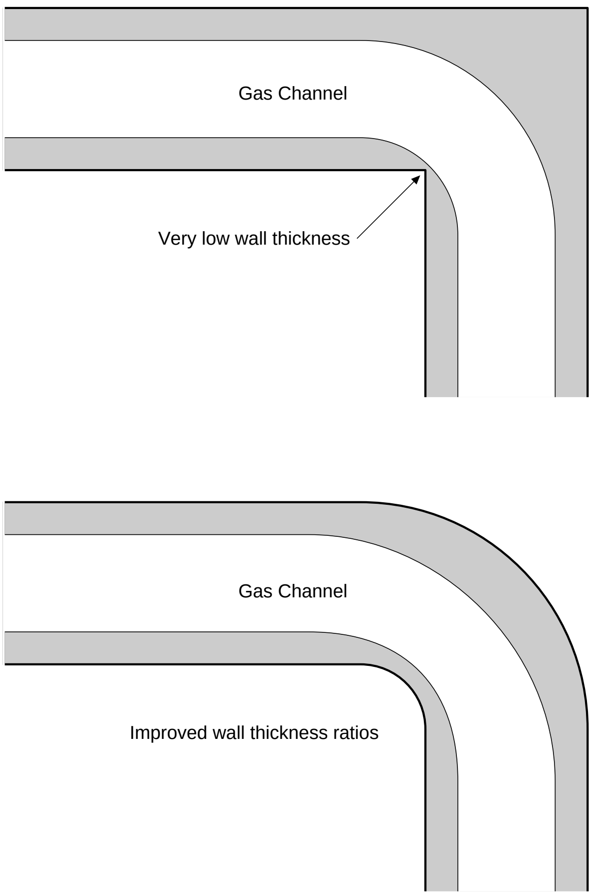
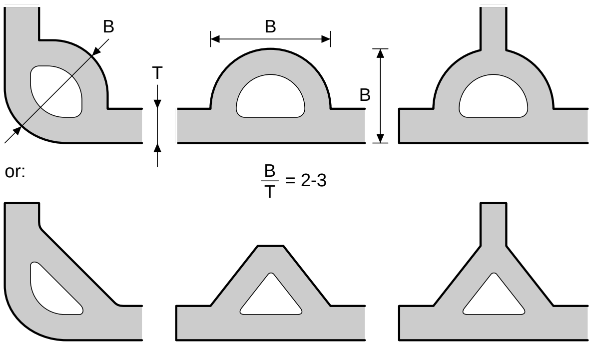


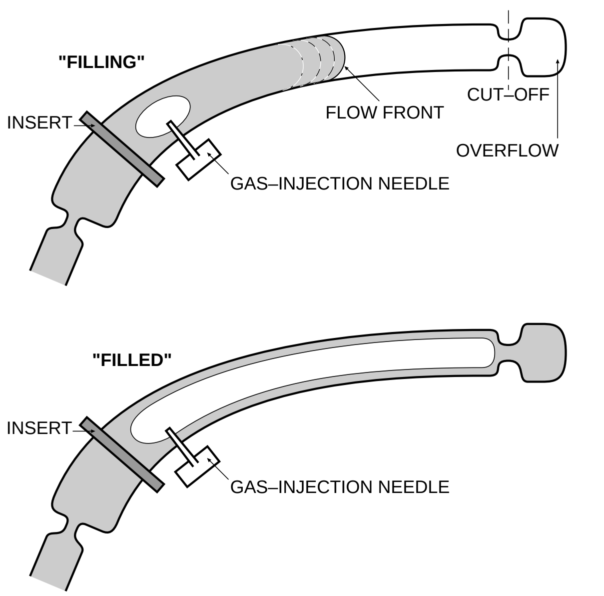
Fig. 9 **Specially designed gas channels for shallow structures.**



In certain applications – e.g. if the part has an integrated function, such as carrying liquids, or if it has connectors attached to it – the gas channel has to extend over the full length of the part, leaving only a thin skin of plastic at the end. In such cases an overflow has to be provided (Fig. 11). Its size will depend on part design and must be determined by process simulation studies, which should help to diminish the need for practical trials.

Inserts are a challenging design problem for gas-injected parts. Inserts have to be properly surrounded by plastic material; the gas channel has to be placed at a certain distance from it. Usually this can be achieved by using a separate gas injection needle placed downstream from the insert (Fig. 11). If the machine nozzle is used for gas injection, more design effort will be needed to ensure that the insert remains properly surrounded by plastic.

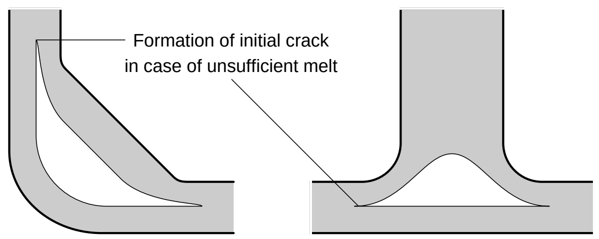
Fig. 11 **Placement of gas-injection needle with inserts**



Material Properties

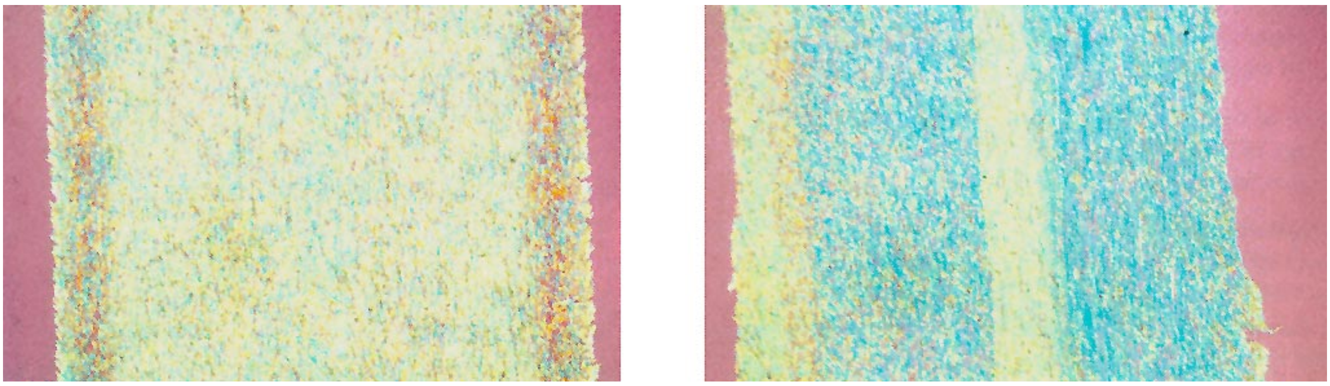
For some materials, DuPont has carried out tests to determine the mechanical properties of end-use parts produced with the gas-injection-moulding process. Tests were needed because several essential parameters in this process which affect the resin's mechanical properties are different from standard injection moulding. The tests showed that the modulus of elasticity and tensile strength of glass-reinforced materials near gas channels are lower because of reduced shear during processing, so that fibre orientation at these points cannot be optimal.

Fig. 10 **Cross sections of too small gas-channels**



These mechanical properties are reduced by around 10% and in extreme cases by as much as 50% compared with standard values.

Fig. 12 compares the structure of a conventional injection-moulded method. Whereas the conventional component has a comparatively high degree of orientation of the glass fibres in the round zones and a rather less orientated arrangement in the centre, the component produced by the internal gas pressure method has a low degree of orientation in the peripheral zone (mould wall). Orientation increases towards the gas channel side, but the centre of the cross-section is characterised by an area of low orientation.



a b

Fig. 12 : Microtomography vierw of a cross-section of a component: (a) formed by traditional moulding (b) formed by gas injection moulding, made of ZYTEL® 70G30 (PA66 with 30% glass fibre).

® DuPont registered trademark

Gate

The gate for gas-injection moulding is different from gates for conventional moulding. If gas-injection is done via the machine nozzle, the gate and runner dimensions have to be about twice as big as for conventional moulding.

The gate should be positioned so that the melt is injected in a wide, even flow along the cavity wall, as in the extrusion process; split flows and confluences, which can lead to unwanted turbulence, should be avoided.

Fig. 13 **Principle of gas-injection nozzle**

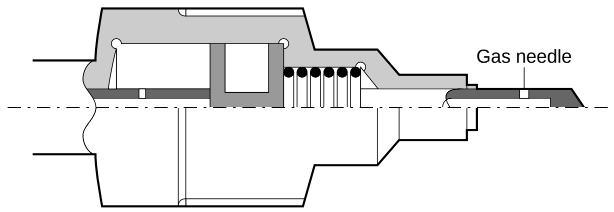
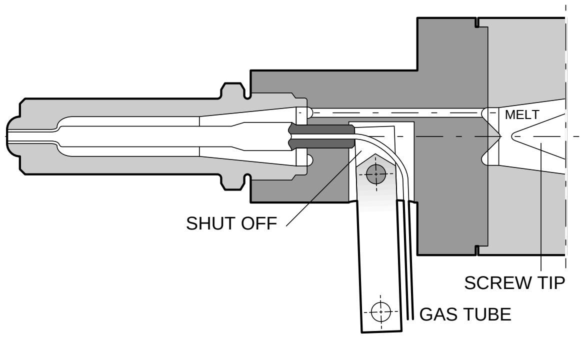


Fig. 14 **Principle of a machine nozzle for gas-injection**



Machine equipment

For the gas-injection-moulding process special equipment is needed to provide the moulding machine with the desired gas volume and pressure at the right time. The principle of a gas-injection unit is shown in Fig.1. The nitrogen is supplied from a conventional pressure vessel into a compressor.
The pressure profile is controlled by a special electronic device via the compressor unit.

Nozzle

The gas is injected via a special nozzle. Some types of nozzle are designed to recover the gas after the cycle via the gas injection equipment. High reliability in production is a vital requirement for such nozzles.

The polymer to be processed is of major importance for the nozzle design. For use with semi-crystalline polymers DuPont offers design assistance for the nozzle.

In general, gas can be injected in two ways:

- via the machine nozzle (Fig.14)
- via one or more special needle(s) direct into the runner(s) or into the part (Fig. 13).

When gas is injected through the machine nozzle, the pressure in the nozzle is allowed to build up and then the gas valve at the tip of the nozzle is opened.

In general a “Shot Off” is used to close the machine nozzle at a given time, so no melt can flow back from the cavity into the barrel.

Using special needles has certain advantages. The gas cavity can be created just where it is wanted in the part. There can be several (independent) gas cavities in one part, created with several needles. (The hole left by a gas injection needle is less than 1 mm in diameter).

The most effective way to place needles is in sections where the melt stays liquid longest.

Aspects of gas-injection moulding

Benefits:

Processing
- lower clamping force
- greater flow length
- lower pressure drop
- substitute hot runner
- simpler, cheaper mould

Design
- lower part weight (reduction up to 40%)
- fewer sink marks
- less warpage
- less shrinkage across direction of flow
- higher torque resistance
- more design freedom with non-uniform wall thicknesses

Limitations:

Processing
- extra equipment
- special nozzle design/gas-injection needles

Design
- wall thickness only roughly predictable, but reproducible
- cross section of gas channels less than 15 to 20 mm
- increased shrinkage in the direction of gas channel flow

Material
- material properties usually lower than in equivalent parts made by conventional injection moulding
- surface quality depends on material

Nearly all DuPont injection moulding resins are suitable for gas-injection moulding, including both filled and glass-reinforced types. Good results have been achieved with RYNITE® 530, ZYTEL® 70G and 72G, ZYTEL® ST101, MINLON® and HYTREL®.

Potential applications for gas-injection-moulding technology.

As a result of the many advantages it provides, there is a large potential for gas-injection moulding technology in almost every technical field.

Some possible applications are:

Automotive:
- Sunshine roof trim
- external mirror housings
- handles
- wiper blade carriers
- covers and panels
- seat frames
- head rests
- pedals
- steering wheels
- knobs and gears
- filter housings

Furniture
- armrests, chair bases, backshells, seat-pans
- housings
- bathroom products

Packaging
- boxes, pallets

Appliances:
- handles
- lawn mower housings

Sports:
- racquets
- hockey sticks
- ski bindings
- ski boots

Gas-injection with DuPont

DuPont technical centres in Europe, Japan and USA offer worldwide support in gas injection technology. In addition to DuPont's main European Technical Center (ETC) in Geneva, other technical centres in Europe where trials and consultations can be arranged are in Frankfurt, London and Milan. A team specializing in gas-injection technology is a resource for customers' research, development and production.

For further information contact:

DuPont de Nemours International S.A.
2, chemin du Pavillon
CH-1218 Le Grand-Saconnex, Geneva
Tel. (022) 717 51 11
Telex 415 777 DUP CH
Telefax (022) 717 52 00
Internet location: http://www.dupont.com/

United Kingdom
DuPont (U.K.) Limited
Maylands Avenue
GB-Hemel Hempstead
Herts. HP2 7DP
Tel. (01442) 21 85 00
Telefax (01442) 24 94 63

Start
with DuPont
Engineering Polymers

Engineering Polymers

05.96 Printed in Switzerland
H-23259 ® DuPont registered trademarks