

Vacuum Foil Infusion

REICHHOLD

The Choice for Vacuum Foil Infusion

Achieving better part functional performance, a cleaner working environment and reduced styrene exposure and emissions are major challenges for the composites industry. For that reason the need for improved working processes has been a priority for resin manufacturers for many years, and has resulted in the development of resin systems with low styrene emissions and low styrene content.

Vacuum Foil Infusion is one of the processes filling the gap in production volume between open moulding processes, like Hand lay up and Spray up (HLU/ SU) and press moulding processes, like Sheet Moulding Compound (SMC). Because of its nature, Vacuum Foil Infusion significantly reduces the exposure to styrene and minimises solvent emissions, whilst allowing production of parts with high strength and stiffness.

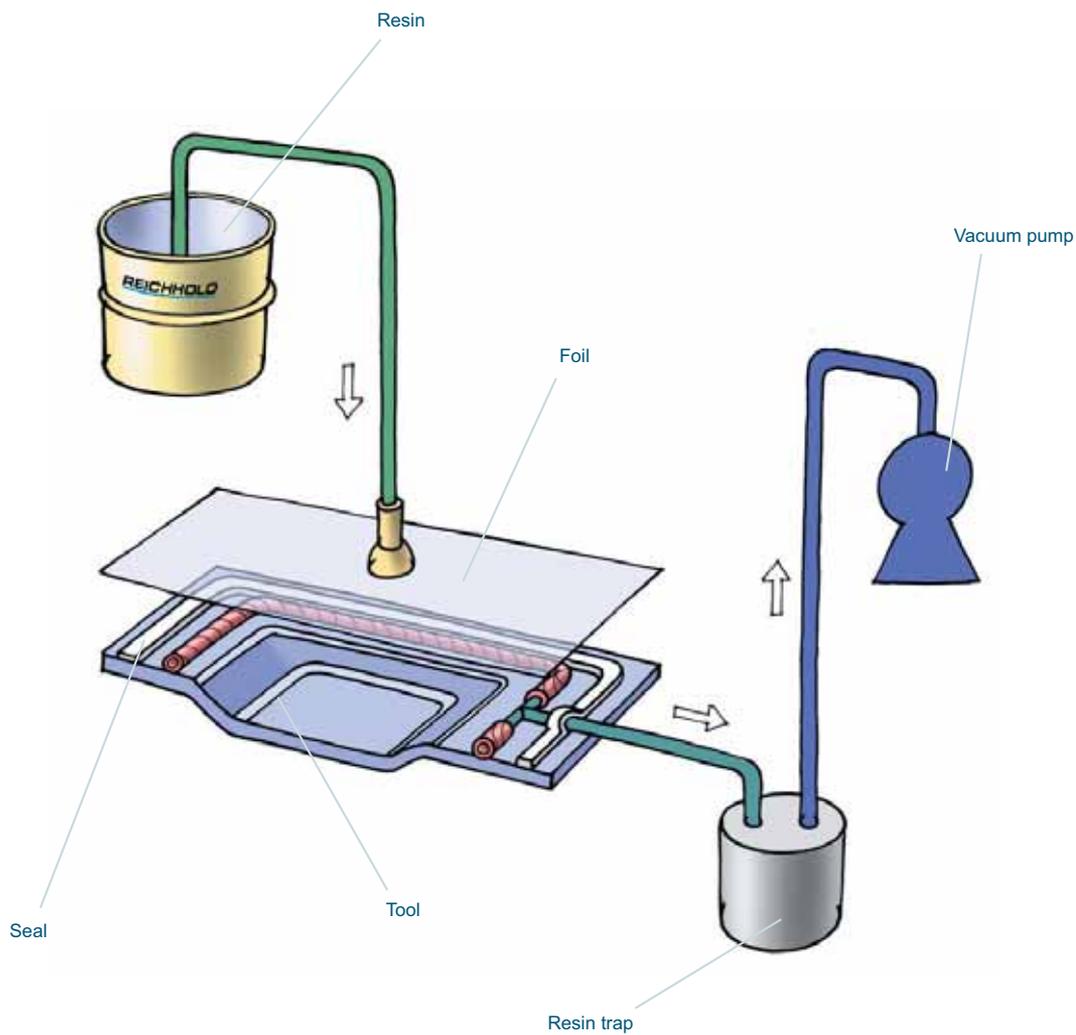


Vacuum Foil Infusion is the first step for the fabricator to consider when moving from an open process to a closed process, especially for manufacturing larger sized products (e.g. boat hulls or decks).

The Process in Steps

The Vacuum Foil Infusion process typically consists of the following steps:

- Preparation of the mould tool
- Application of gelcoat, barrier coat and/ or skin laminate
- Placement of reinforcement and/ or core materials in the tool
- Foil and seal placement
- Resin injection by application of vacuum
- Curing
- Demoulding



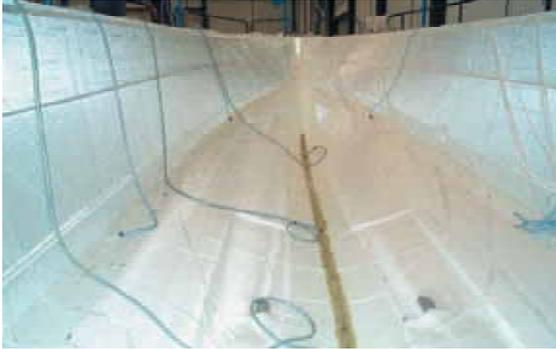
This guide will help to better understand the benefits and limitations of the Vacuum Foil Infusion processes and allow easier decision making on process parameters and key raw materials.

Benefits of Vacuum Foil Infusion

Advantages	Details
Low mould/ tool investments	Only small modifications are required to existing open moulds
Improved laminate mechanical properties	Higher density laminates with increased glass content
Good reproducibility: reduced dependence on workmanship	As long as process parameters and reinforcement package design are kept constant
Large products can be made in a closed process	Highly effective for components with large surface area
Very low styrene exposures and emissions	Reduced ventilation cost possible
Cleaner production	More pleasant work environment
Reduced material waste compared to Spray up processes	Reduced resin spillage and reinforcement edge trimmings
Reduced cycle times possible	For more complex products, thicker laminates, sandwich constructions and large products
Low cost for large, simple products	

Points of Attention	Details
Higher reinforcement material cost	Typically more sophisticated fabrics and roving/ fabric combinations are used compared to Spray up
More time consuming, especially for smaller products	Cutting and placing of reinforcement tends to take time, depending on product design and fabrication set-up/ lay-out
Increased waste from hoses, foils, seals etc.	Non re-usable materials
Increased cost for smaller, more complicated parts	Because of design limitations, differences in handling and preparation
Higher risk of print-through for gelcoated products	Resulting from increased shrinkage associated with single shot infusion

Process Overview



A normal, female Hand lay- or Spray up (HLU/ SU) mould can be easily modified for Vacuum Foil Infusion by extending the flange to enable clamping/ sealing of the foil, and possibly by adding a peripheral gate or channel for the resin feed.



After the preparation of the mould (with mould release, gelcoat, barrier coat and/ or skin laminate), install the vacuum pump and resin trap; after placing the reinforcements and foil, the infusion process can start.



The plastic foil is kept in place and drawn down by vacuum. When the 'mould system' has been checked for possible leakages, the transfer of the resin can begin. The vacuum port and resin feed lines are connected to the system. As the required vacuum is reached, the resin reservoir is opened, and the resin flow starts.



When the reinforcement package is fully impregnated with resin, the resin feed is cut off. Still under vacuum, the laminate is left to cure.

Product Selection Considerations



When selecting and designing the optimised combination of resin and reinforcement, there are two important parameters to consider:

- The end product requirements (mechanical and physical properties)
- The process requirements (desire to optimise manufacturing speed, labour, quality and emissions)

The overall laminate strength and stiffness are determined by the laminate thickness, the combination of reinforcements, and obviously by the resin matrix that holds the reinforcements together. Any local further strengthening and stiffening may be obtained by using tailored fabric/ reinforcement combinations or by the inclusion of ribs.

Vacuum Foil Infusion processes allow making the laminate in one step, rather than building the laminate in multiple layers over several days. This translates into immediate benefits such as reduced cost, increased strength and stiffness, reduced laminate thickness, and reduced weight. However, at the same time the control of surface smoothness requires more attention, due to the fact that the total laminate package will shrink more and print-through can become a greater issue.

Surface quality and smoothness can be largely improved by using a barrier coat, alone or in combination with a skin laminate. This brings the secondary benefit of improved hydrolytic stability and osmosis resistance.



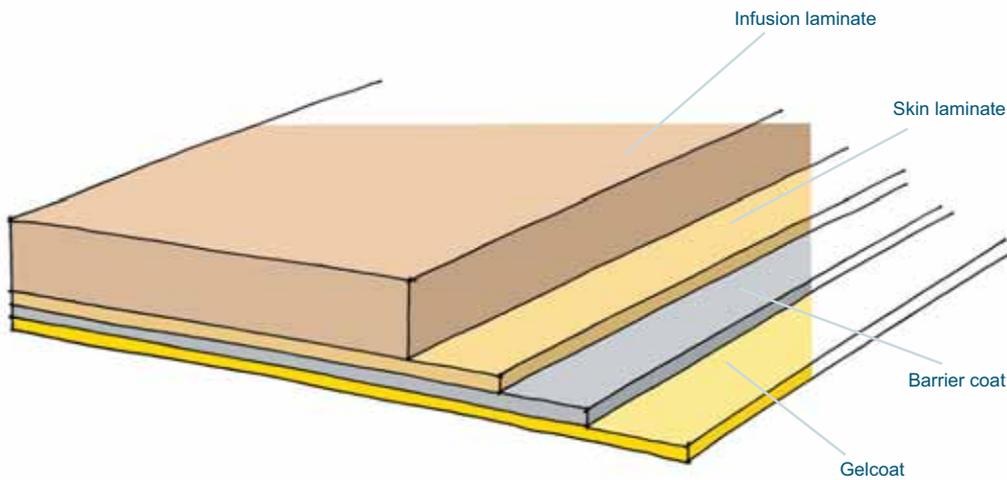
Laminate Build-up

Gelcoat

Non-reinforced coloured layer providing surface aesthetics and laminate protection. Different gelcoats are available that can offer excellent protection to weathering and a significant reduction in the emission of volatiles during application.

Barrier coat

Non-reinforced layer applied directly behind the gelcoat, for optimising the surface smoothness and hydrolytic stability. Can be used as an alternative to skin laminates in RTM and infusion processes in order to reduce labour time. In combination with a skin laminate superior surface properties can be obtained.



Skin laminate

Reinforced layer behind gelcoat and/ or barrier coat improving surface strength and hydrolytic stability. A skin laminate can be integrated into the total laminate construction.

Infusion laminate

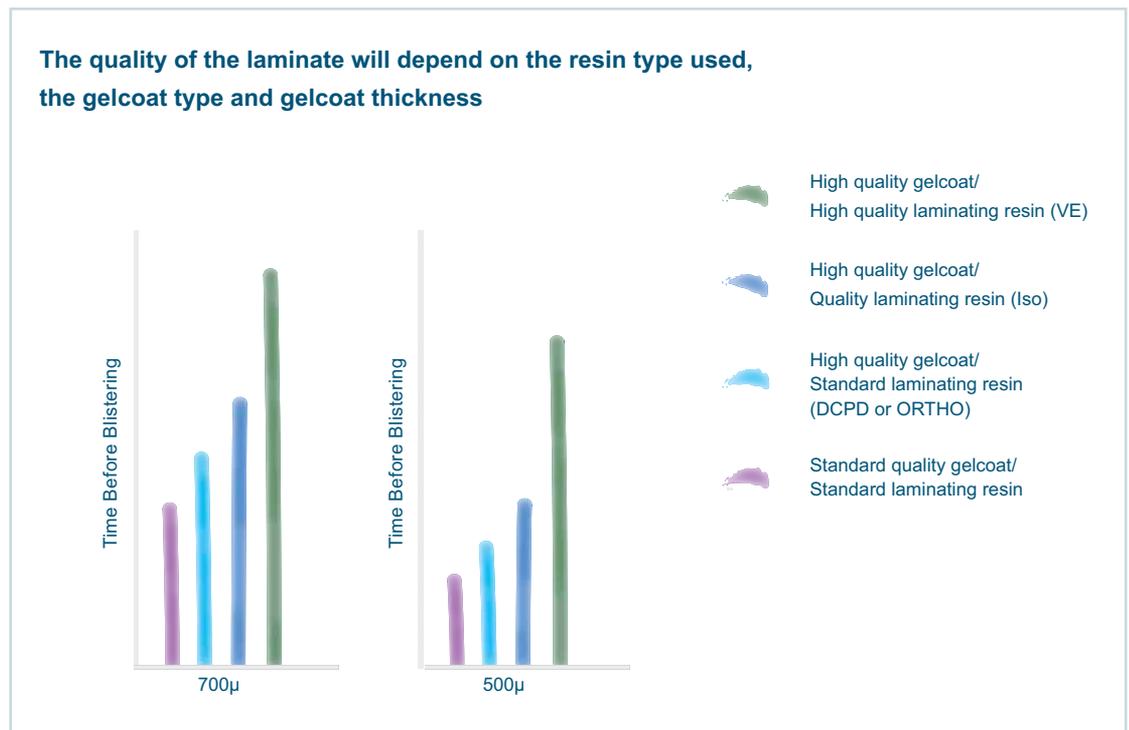
Reinforced laminate construction providing overall strength and stiffness to the construction. May contain different sandwich layers and/ or reinforcement combinations to reach the optimum flow and end laminate properties.

Infusion Resin Selection

The resin selection for Vacuum Foil Infusion should be made taking into account end use product requirements. This may require consideration of laminate properties, like mechanical and physical performance, chemical resistance, fire retardancy etc. In addition processing parameters like viscosity, geltime and reactivity are also important for the resin selection process.

Viscosity is the parameter guiding the flow in a given reinforcement package and should be carefully selected. The lower the viscosity the easier the flow will be, but if the viscosity is too low air might become entrapped in the laminate leading to a localised reduction in mechanical properties. If the viscosity is too high the resin flow is restricted, resulting in a very long injection/ filling time.

Most of Reichhold's infusion resins have a viscosity between 90-350 mPa.s, which provides a good compromise between filling time and laminate quality.



Also the gel and cure characteristics of the selected resin are important. Reichhold can support you in choosing the cure systems (taking into account filling time desired), laminate thickness and other considerations. The geltime must be selected so that sufficient time is available for complete filling of the mould, with the addition of a safety margin for managing possible stops etc. during injection. The geltime of the resin is largely dependent on temperature: high temperatures result in shorter geltimes, lower temperatures result in longer geltime.

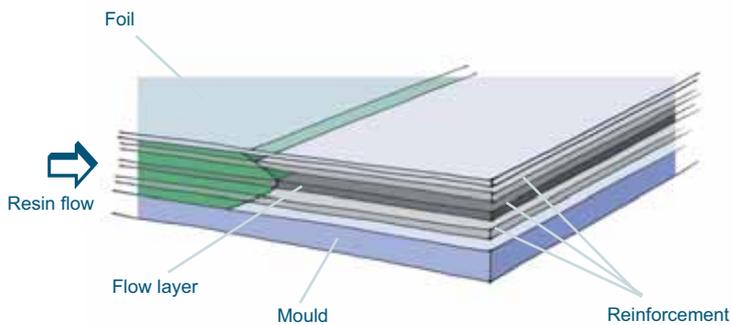
Fillers are often added to the resin to improve specific properties (such as increasing laminate stiffness) or for raw material cost reduction. By using Aluminium Trihydrate (ATH) fire retardant properties can be obtained. The particle size of the filler is important; viscosity studies show that a particle size of 6 microns is best suited for Vacuum Foil Infusion due to viscosity stability and possible filtering. Adding filler increases the resin mix viscosity, resulting in longer injection times.

For advice on resin selection, please contact your Reichhold Sales or Technical Service representative.

Reinforcement Selection

It is recommended to use a reinforcement build-up that provides a combination of good flow and required laminate mechanical properties. If it is required to produce a part with complex design and difficult angles, reinforcements with good drapeability should be used.

When producing parts with vertical surfaces, it may be necessary to attach the glass mat to the mould to avoid it moving out of position. Clamps or spray glue can be used to attach the materials.

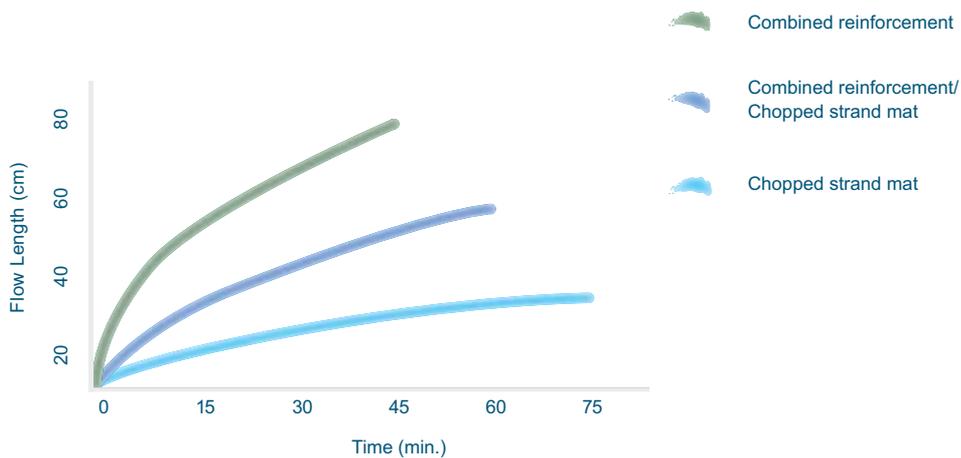


Flow through the reinforcement

This method is mostly suited for short flow length, when the part is small or narrow. The biggest advantage is that the surface may be smooth and thus easy to place the injection and vacuum points.

Different reinforcements can have different flow properties. In general there is an inversely proportional relationship between the flow properties and the mechanical properties. Finding the right balance between the two is often the best solution. For example one or more layers of a mat with good flow properties are placed in the core of the reinforcement package acting as a flow layer, whilst the rest of the reinforcements (e.g. chopped strand mat) will provide mechanical strength.

Flow properties



Dedicated reinforcement products are available for Vacuum Foil Infusion processes including types where a flow layer is covered by two layers of standard reinforcement and stitched together.

Reinforcements for Improving Surface Finish

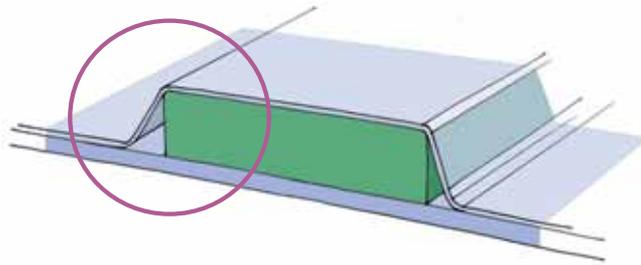
A surface veil, tissue or synthetic felt is sometimes used for improving surface finish. The selected material needs to have good drapeability and flow in order to avoid entrapment of air near the surface. A synthetic surface layer is recommended where a more resin rich surface layer is desired, when parts without a gelcoat will be exposed to harsh environments.

Core Materials

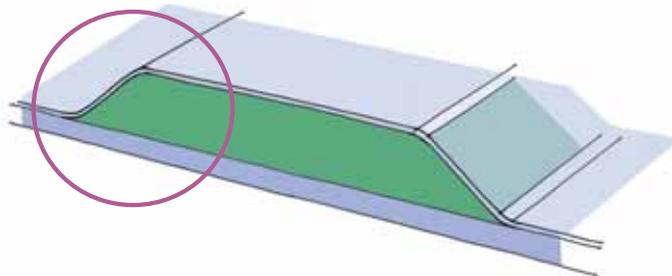
Specially prepared, closed cell core materials are available for Vacuum Foil Infusion, prepared with surface grooves/ flow channels that enable easy flow.

These core materials tend to have tapered ends/ edges for avoiding the sharp change between the sandwich and single skin laminate. The sharp edges can result in resin rich areas which can lead to excess shrinkage and high peak exotherms.

Incorrect radius



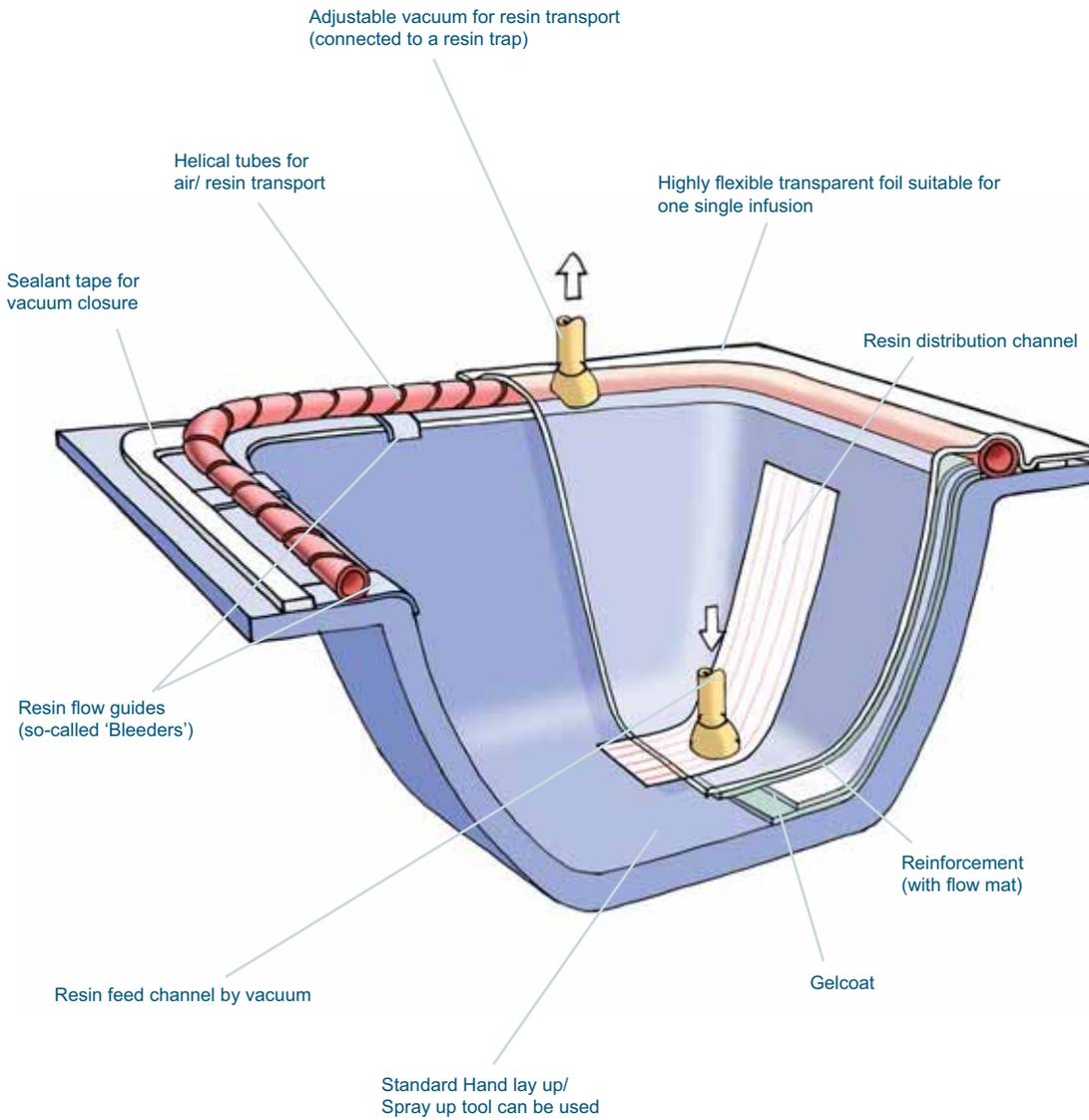
Correct radius



In many cases it will be required to drill/ nail holes in the core, to ensure the resin can flow with the same speed on both sides of the sandwich core.

The temperature in the laminate can be relatively high during cure, due to the insulating nature of the core material. The temperature resistance of the core material must be sufficient to avoid possible shrinkage causing collapse of the core during cure.

Mould Setup



The Vacuum Foil Infusion method is typically considered cost effective for production of 50 - 1000 parts per tool per year.

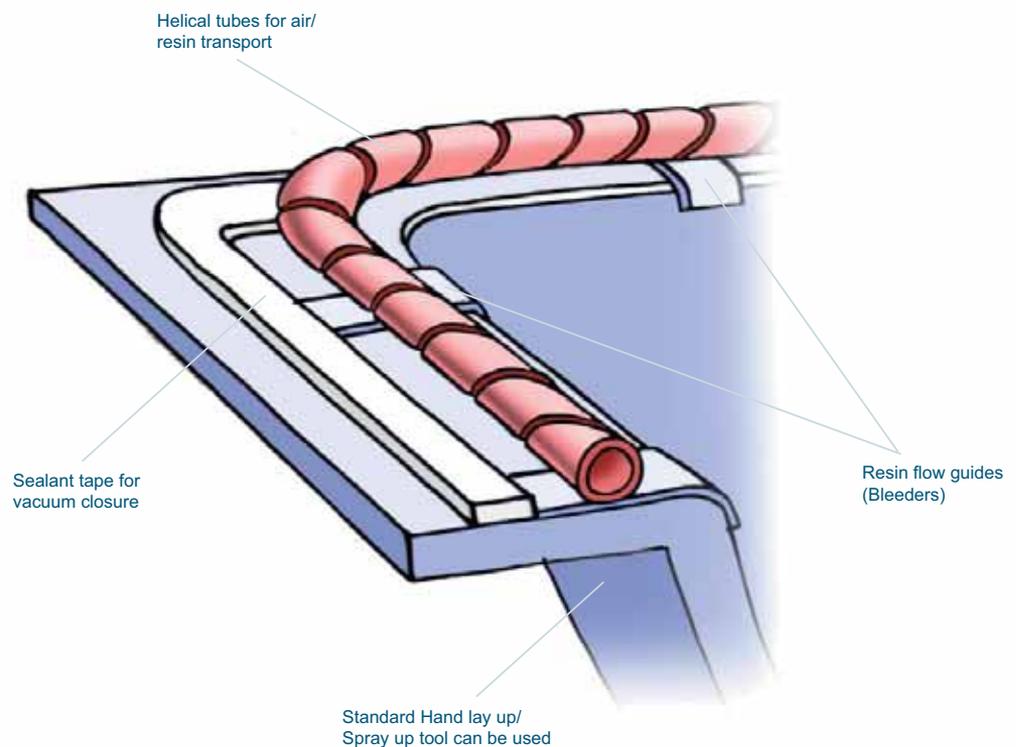
Mould Details

In principle it is possible to use existing Hand lay up and Spray up moulds, provided they are a one piece, solid mould type with mould laminate free from leakage (multi-piece moulds can be built, but precautions need to be taken to make split-lines airtight and leak proof).

If the mould has a tendency to draw false air under vacuum, the outer surface can be sealed off with a proper coating. There must be sufficient space on the flange for the sealing and/ or clamping system. Minimum width of the flange is approximately 15 cm.

The size of the product has in principle no limits. However, the width of the foil can be a point of limitation for very wide products, as sealing/ connecting two foils can cause vacuum leakage problems.

The foil is fixed on the flange by double-sided sticky tape.



As with all composite mould designs sharp angles and corners should be avoided. De-moulding will be easier if certain draft angles and radius rules are applied at the part design stage. In infusion this is even more important as compacted reinforcement materials over sharp tooling edges can lead to resin flow problems and air entrapment. Aim for minimum 30° draft angles for parts less than 80 mm deep and 50° for deeper parts.

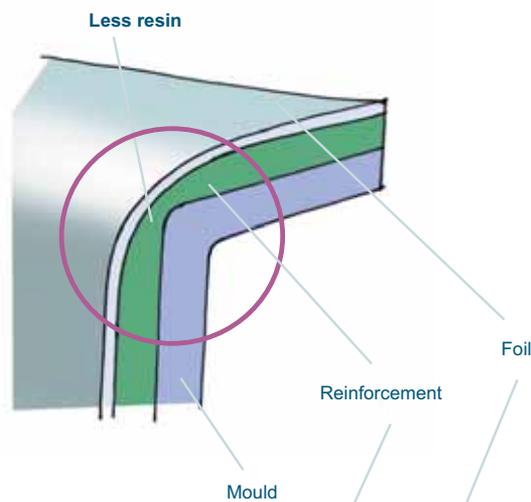
Minimise introduction of bosses and ribs that will complicate the accurate placing of reinforcements. Inserts are possible but radii rules should still be applied and careful dimensioning and positioning within the mould cavity is required to ensure even part thickness.

The stiffness of the mould must be sufficient to resist the vacuum pressure. In principle this means that a stiffer mould often is required than for open moulding. From practical experience it is known that most moulds are heavier and stiffer than strictly required and are usually found suitable without major adaptation/ modification.

Corners and Angles

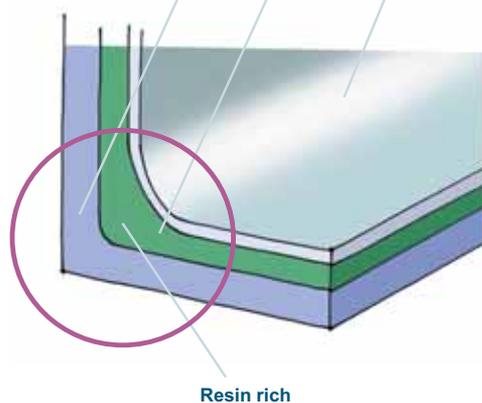
Sharp edges

Over sharp edges the resin tends to flow more slowly, due to increased compression of the reinforcements in these areas. Care should be taken and the injection strategy/ pattern should be designed with this in mind. The corner and edge radii should be as large as possible so this problem can be avoided, especially in thick laminates.



Sharp corners

In sharp corners and angles the resin tends to flow faster, because it is more difficult to get the same compression of reinforcement and foil compared to equivalent flat area sections. Beware that the glass content can be even lower if the film is stretched too far. Extra reinforcements or other filling materials, localised in these areas, can be a solution for difficult shapes.



Injection Strategy

One of the challenges in Vacuum Foil Infusion is the choice of the right 'injection strategy'. This includes making decisions on parameters like the location of the injection/ vacuum points, the choice of the reinforcement combination, use of helical tubes, core materials and net.

How to obtain the fastest possible filling of the mould, whilst achieving the right product properties?

Alternative 1: Flow through helical tubes or other distribution channel

For larger flow lengths (in excess of 50-80 cm) the flow through the reinforcement alone might not be sufficient. The filling time for the mould can become too long and production too slow. One way to speed up the filling is to use helical tubes for resin transfer where the tube and layer of peel-ply is placed between the film and the reinforcement.

One disadvantage with this method is that prints of the helical tubes/ peel-ply will remain visible on the surface. If the surface must be smooth then grinding will be required. For single skin laminates it is better to use flat distribution channels to avoid print through on the gelcoat side.

The helical tubes are normally spaced 70-120 cm apart, depending on the size and shape of the product. The spacing is a typical parameter decided during the prototyping of the product. The hose placement is important to avoid incorrect flow patterns and possible inclusion of air.

Alternative 2: Flow through a net

With this method the resin flow mainly takes place in a net cloth that is placed between the film and the peel-ply. The flow channels shall be as much as possible in the natural flow-direction, otherwise dry spots may occur.

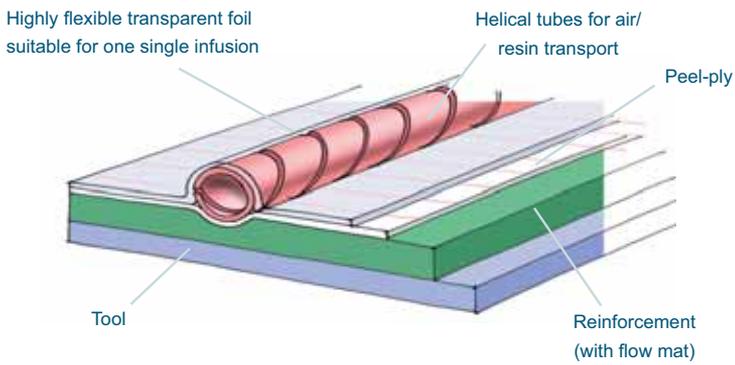
This alternative typically results in a longer filling time compared to Alternative 1. After removing the peel-ply, glass fibres are close to the surface resulting in the need for less surface treatment.

Alternative 3: Flow through pre-cut channels in a core

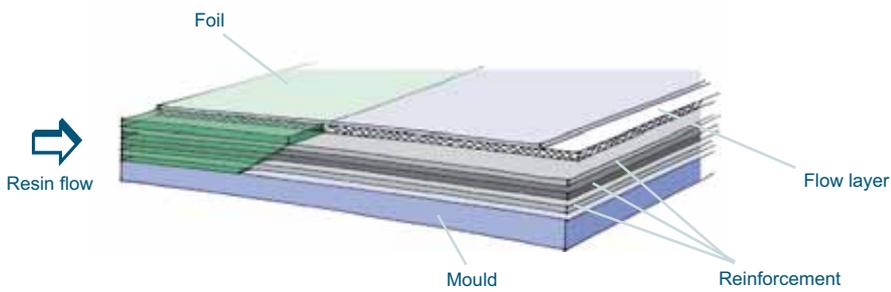
If the product contains a core material, this can be exploited for improving the resin flow, through flow channels or grids in the core. Several core suppliers produce cores with pre-cut flow channels.



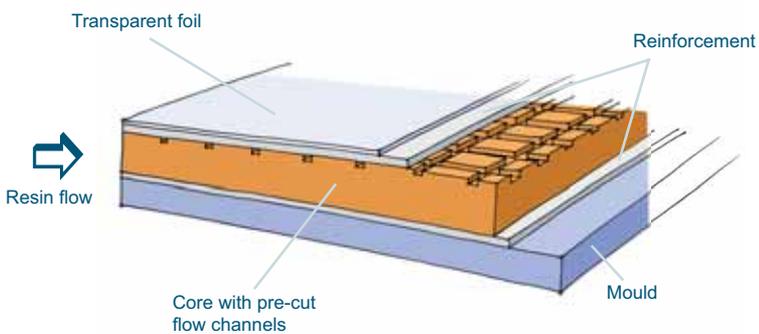
Alternative 1



Alternative 2



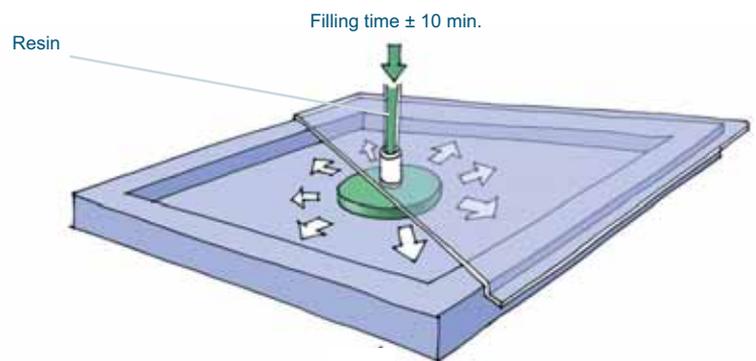
Alternative 3



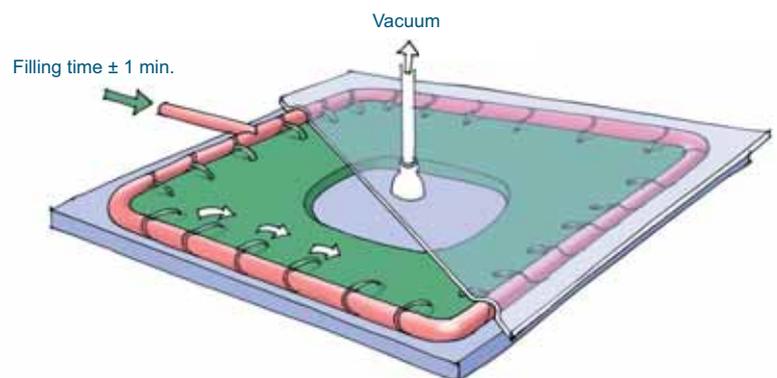
Injection Strategy

As a general rule the resin should be injected along the edge (peripheral) rather than through a point. Injection through the edge results in faster flow. The option of the injection point in the middle shows less problems of air entrapment during leakage.

Point injection



Peripheral injection



Processing Conditions

The vacuum level during injection is normally 0.7-0.9 bar. Higher vacuum levels can result in polyester resin boiling at the flow front causing air-entrapment, as the lower pressure reduces the boiling point of the resin solvents.

Near the resin inlet the laminate tends to be thicker, since the laminate will be lower in density due to the fact that the lower vacuum level results in less reinforcement compression. Reduce the vacuum level towards the end of the injection process to compensate for this effect. Decrease the vacuum level with 0.2 bar versus the pressure during the earlier injection phase. When the mould is completely filled reduce the resin inlet to a minimum and hold the vacuum until the peak exotherm is reached.

Equipment

When changing from Hand lay up or Spray up processes to Vacuum Foil Infusion, additional equipment will be required (extra to the modification of the mould flange).

Foil

The foil has to be styrene resistant and flexible; normally a 300-600% tensile elongation foil is selected. Preferably the foil should be translucent allowing observation of the flow front during filling. Thickness of the foil is normally 50 micron. The foil should be of a recyclable material (due to one time use) and must be free of pin holes.



Foil types that have shown to work the best are nylon based. The foil should be wide enough to cover the whole part. Splicing of foils should be avoided, as this can often cause vacuum leakage.



Hoses

All hoses and connections must be styrene resistant and able to withstand the applied vacuum level. Use of transparent hoses is recommended to track the resin flow.

Helical tubes are often used for resin transport. They must not be stretched excessively when placed, otherwise the foil can be drawn into the hose and obstruct the flow.

Equipment

Vacuum pump

The vacuum pump should be able to maintain a vacuum of at least 0.9 bar, without overheating. The pump must be connected to a resin trap in order to prevent resin from getting into the pump. The exhaust air from the pump will contain styrene and should be handled by a suitable ventilation system.

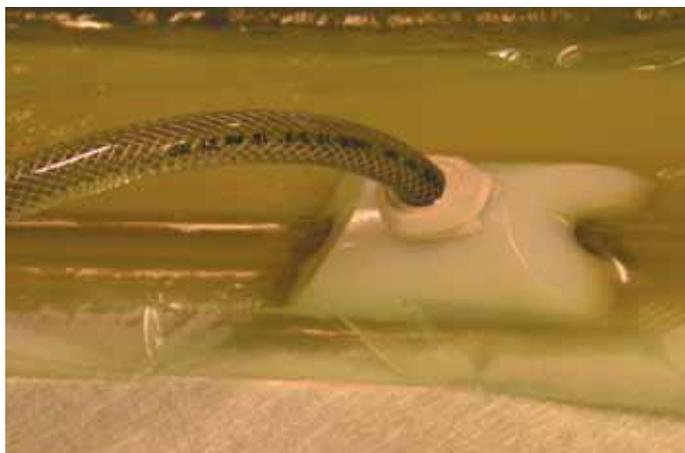
Sealant tape

Sealant tape has proven to be very effective for sealing the foil on the flange and for repairing air leaks during injection. The tape is available in various dimensions.



Vacuum connecting parts

Special components are available to provide the connection between vacuum and reinforcement through the foil.



Quality Control

Raw material control

Viscosity control

Resin viscosity controls the speed of wetting and filling of the fibre reinforcements. Resin manufacturers supply resins within a quoted range of viscosity at a particular temperature using a variety of test equipment; however a simple check using a thermometer, stopwatch and a flow cup can help maintain consistency, especially when fillers or additives are being used.

Geltime and reactivity

The geltime must be long enough to allow the tool to be filled completely before the crosslinking begins.

- Balance or graduated container (500/ 1000 ml)
- Pipettes (1-10 ml)
- Thermometer (alcohol or thermocouple)
- Stopwatch

NB: Test the geltime in the working area at actual room temperature.

Temperature control (workshop, resin, mould)

- Thermometers (general use, immersion and surface thermocouple probes)
- Infra-red non contact temperature gun



Composite control after demoulding

Hardness/ cure control

The Barcol 934-1 hardness meter gives a rough indication of the state of cure of the part on de-moulding by testing surface hardness.

Even with the best quality control systems in place, different problems and difficulties can occur during processing, with defects in the finished product as result.

For advice about trouble shooting, please contact your Reichhold Technical Service representative.

