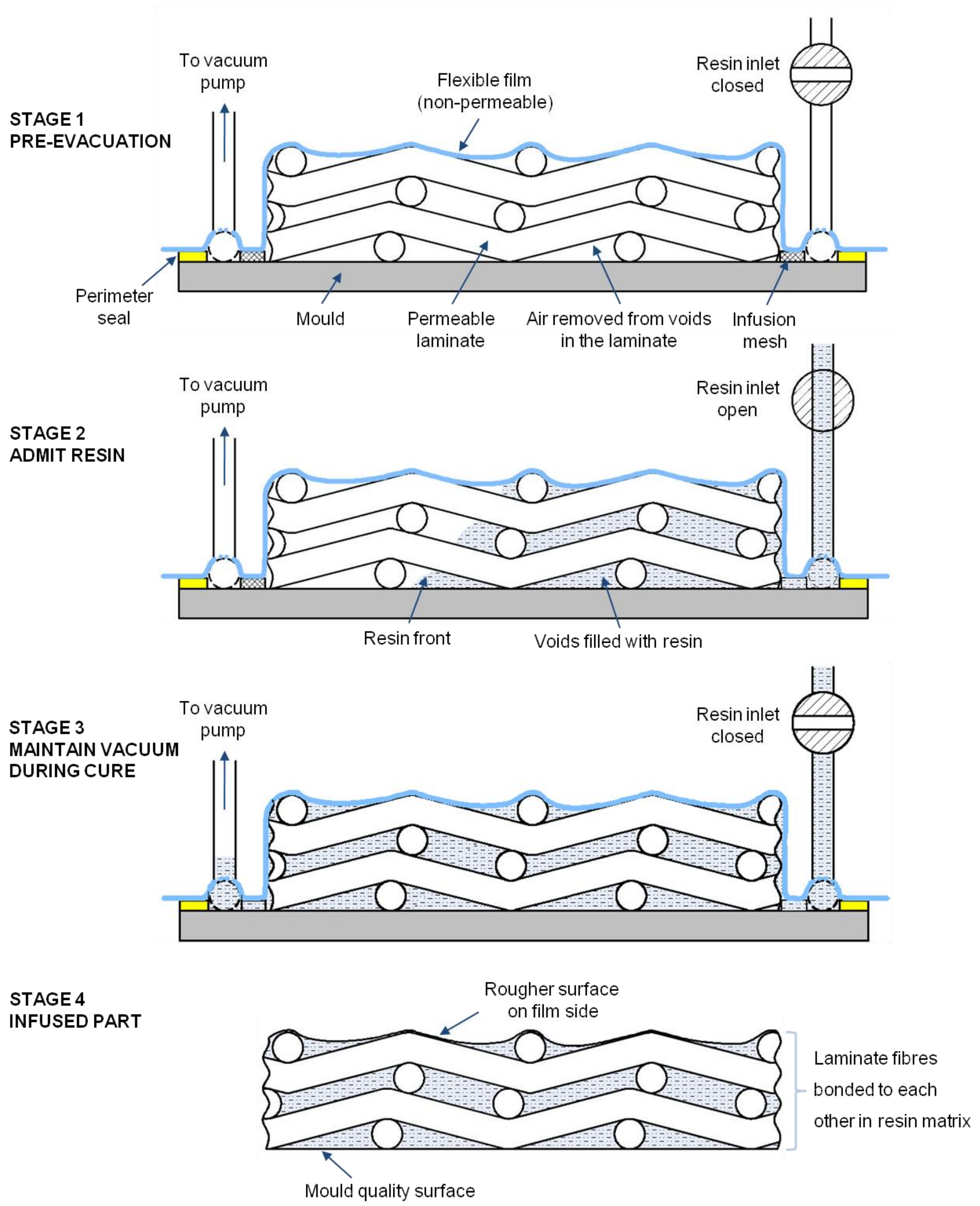
Vacman's notes
Stuff we've learned over 25 years connecting vacuum with composites

Updated June 2012

What is resin infusion (or vacuum infusion)?

In the field of composites, resin infusion is a process where the voids in an evacuated stack of porous material are filled with a liquid resin. When the resin solidifies, the solid resin matrix binds the assembly of materials into a unified rigid composite. The reinforcement can be any porous material compatible with the resin. Typical materials are inorganic fibres (with glass fibre being most common), organic fibres such as flax, or combinations of fibres with other materials such as closed cell foams, balsawood, and honeycomb. Porous materials can also be infused onto the surfaces of non-porous materials such as sheet metal. Resins are usually thermosetting types, but thermoplastic resins can also be used for infusion.

A key part of the process is the evacuation, or removal, of the air from the porous material prior to admitting the resin. The air needs to be removed from the porous material to allow the resin to take its place. In its simplest form the process can be broken down into the following stages:



Why use the infusion process?

The resin infusion process is a cost effective method of manufacturing high quality and high strength composite parts that are required in relatively low quantities, say less than a few hundred identical pieces per mould per year, or physically large parts which are difficult, or prohibitively expensive to make by any other method.

Benefits of the infusion process

- Low investment cost. Typically little more investment than that required to make composite parts using hand lay-up in open moulds.
- Capable of producing minimum weight, high performance laminates with properties comparable to those of laminates produced by more expensive processes such as autoclave cured prepreg.
- Infusion allows the reinforcement materials to be handled dry. This avoids the need for laminators to have contact with the resin, significantly reducing workforce exposure to the resin. Allergic reactions to resins such as epoxy can be avoided.
- The process is carried out within a “closed” system; that is within the void between a sealed bag and a mould, or between 2 sealed moulds. Hence there is minimal exposure of the uncured resin to the atmosphere. The potential for harm to worker health and to the environment from volatile resin components is consequently reduced. Because of the low emission of volatiles, factory ventilation costs can be reduced. This can be a worthwhile benefit in cold regions relative to high volatile emission processes such as chopped strand spraying or hand laminating.
- When performed under a flexible film, infusion uses the minimum amount of resin needed to fill the voids in the dry laminate. Especially for smaller/repetition parts where multiple-use flexible films are practical, infusion offers an opportunity to reduce manufacturing cost compared with hand lay-up, while enhancing laminate quality.
- Infusion is a particularly practical and cost effective solution for the construction of large, high strength/light weight one-piece parts, such as boat hulls, wind turbine blades, bridge beams and building cladding panels.
- The number of components required to make a part can often be significantly reduced using infusion.

What are the limitations of infusion?

Resin infusion should be considered a “work in progress” manufacturing technology. At its present stage of development, infusion has some limitations. These limitations are:

- Infusion is a relatively slow manufacturing process. It is usually not worth considering for applications requiring high production rates where another manufacturing solution is feasible.
- For one-off or large parts where multiple-use flexible films or top moulds are not practical, or are prohibitively expensive, the process can result in considerable waste (vacuum bag film, resin tubing, some of the vacuum tubing and, possibly, flow media and peel ply if flow medium cannot be left in the laminate).

Other names for resin infusion and related vacuum processes

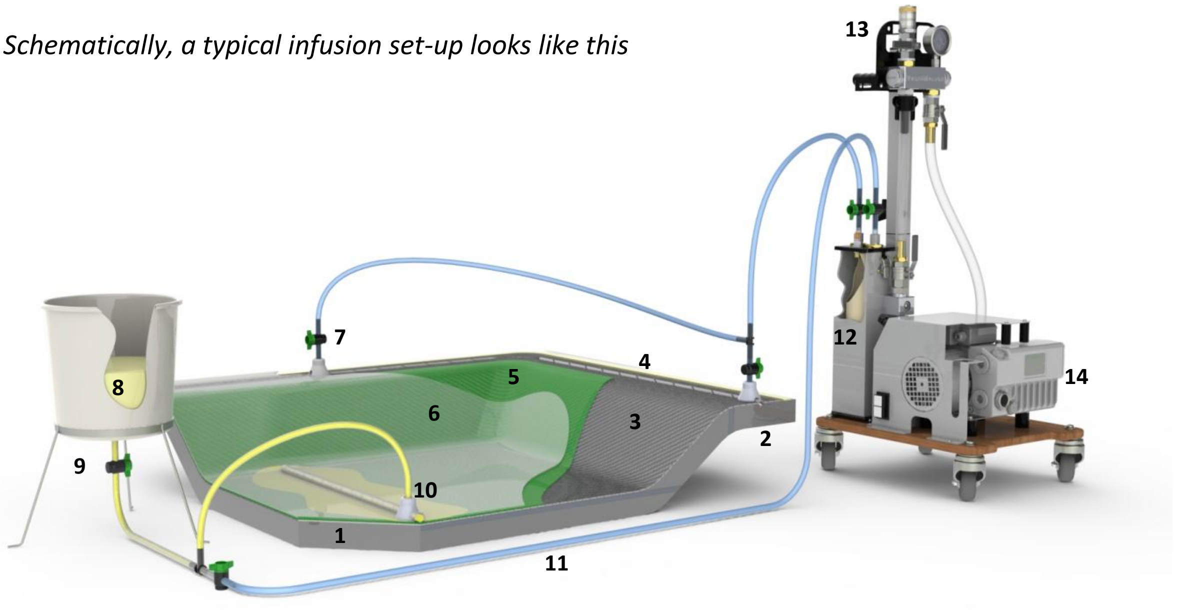
There are many names and acronyms for the resin infusion process or very similar processes. Some examples are:

- Double (flexible) bag infusion. A process where one vacuum level is applied to the reinforcement positioned between the mould and an inner flexible bag and a second vacuum level (usually a higher vacuum level) is applied to a porous medium held between the inner vacuum bag and a second flexible vacuum bag. This process is not to be confused with the NASA developed DVB process. See next.
- DVB process. In the NASA developed double vacuum bag process a rigid perforated shell is interposed between 2 flexible bags. Separately controllable levels of vacuum may be applied to the inner bag or to the void between the 2 bags. The DVB process is particularly suited to the manufacture of composite parts involving resins which release water or solvent vapours during curing.
- CAPRI process. Controlled Atmospheric Pressure Resin Infusion. This is a version of infusion patented by Boeing Aircraft Co.
- Closed moulding. This is a general term covering a wide range of composite manufacturing processes conducted within some form of enclosed space, e.g., between a rigid mould and a flexible film, or between 2 rigid moulds. Resin infusion is one example of a closed moulding process.
- Liquid Composite Moulding.
- LRI. Liquid Resin Injection.

- MVI. Modified Vacuum Infusion (Airbus technology).
- RFI. Resin Film Injection.
- RIFT. Resin Injection under Flexible Tooling.
- RTM. Resin transfer moulding. This most often means a process where resin is injected into a pair of clamped matched moulds at pressures greater than atmospheric pressure. However, RTM is sometimes applied to a vacuum infusion version of this process. See RTM Light.
- RTM ECO. See RTM Light.
- RTM Light (Lite). Vacuum variation of RTM, where resin is drawn into an evacuated cavity between a male mould and a matching female mould. If the perimeter flanges around the moulds are extended and sealed off from the mould, vacuum may also be applied between the two flanges and used to hold the two moulds together. Where vacuum is used to clamp the perimeter flanges, the vacuum system must be capable of producing 2 individually controllable vacuum levels; one for the laminate region and one for the flange clamping region.
- SCRIMP Process. Seeman Composites Resin Infusion Molding Process. This was one of the earliest infusion process patents.
- Vacuum infusion.
- VAIM. Vacuum Assisted Injection Moulding.
- VAP. Vacuum Assisted Process. This is a process variation patented by EADS.
- VARI. Vacuum Assisted Resin Injection.
- VARIM. Vacuum Assisted Resin Injection Moulding. (Lotus Cars).
- VARTM. Vacuum Assisted Resin Transfer Moulding.
- VIM. Vacuum Infusion Moulding.
- VIP. Vacuum Infusion Process.

Single vacuum level infusion using a flexible bag in more depth

Schematically, a typical infusion set-up looks like this



Key

1	Mould, leak tight and pre-treated with mould release	7	Vacuum control valve(s). May be just a clamp on the vacuum tube
2	Sealing flange. Typically 75 mm (3”) to 150 mm (6”) wide	8	Resin (normally positioned below the part)
		9	Resin control valve. May be just a clamp on the resin feed tube
3	Laminate materials. Placed in mould in DRY state		
4	Permeable vacuum line under the bag	10	Resin entry point(s)
5	Disposable materials (typical). Peel ply above the laminate and flow medium above the peel ply	11	Optional vacuum line for pre-evacuation
		12	Resin trap with internal catchpot
6	Vacuum “bag”. May be nylon (disposable) or a reusable film such as silicone rubber	13	Vacuum controls
		14	Vacuum pump

Critical elements of the infusion process

The resin infusion process can be reduced to the following elements, with the aspects emphasised in capitals being critical to the success of the process:

1. A stack of DRY material(s) to be laminated is placed in a LEAK-TIGHT mould.
2. A LEAK-TIGHT flexible film (commonly known as a vacuum bag) is placed over the laminate and SEALED to the mould beyond the perimeter of the laminate. Where multiples of the same part are to be made, the film may be moulded to the shape of the part and be reusable.
3. A minimum of two connections are made to the bag; one to permit air to be removed from the cavity between the bag and the mould and the other to allow liquid resin to enter.
4. With the resin entry line temporarily CLOSED, the cavity between the bag and the mould is evacuated by a vacuum pump. The level of vacuum necessary will vary depending on the permeability of the materials (i.e., with the ease by which air and resin will flow through the materials) and by the complexity and desired quality of the final part. Except when the laminate could be damaged by excessive compression (e.g., a low density foam core), best results will be achieved by evacuating to the maximum level the vacuum pump is capable of – say to better than 95% of the maximum possible vacuum.
5. After this preliminary evacuation, the bag and mould should be temporarily closed off from the vacuum pump and the level of vacuum remaining in the part observed on a vacuum gauge. If the vacuum level remains constant, or at least reasonably constant, the mould and bag will be considered sufficiently LEAK-TIGHT and the process can continue to the next stage. If, however, the vacuum level deteriorates at a faster level than can be accepted, air will be leaking into the evacuated cavity and the process should not continue. In this case, the air leaks must be found and eliminated before proceeding further. Acceptable leak back rates will vary depending on part size and desired laminate quality. For large parts such as boat hulls, a leak rate of less than 3 mbar/minute (approximately 1" Hg in 10 minutes) will be acceptable. For small, or critical parts an acceptable leak back rate might be 10% of the above, say 3 mbar in 10 minutes, or 0.1" Hg in 10 minutes.
6. Once a satisfactory level of leak-tightness has been achieved, the line to the vacuum pump can be reopened. The resin supply container can be filled with mixed resin and the line to the resin supply can be opened. With the resin supply line open, liquid resin will be forced into the part by the PRESSURE DIFFERENCE between atmospheric pressure acting on the resin and the level of vacuum in the part, plus or minus the static head of the column of resin arising from the elevation of the resin supply relative to the part. If resin feed lines and vacuum off-takes have been correctly positioned on or around the dry laminate stack before the bag is placed, the liquid resin will seep or INFUSE through the whole laminate.
7. Depending on the resin system used, the VACUUM LEVEL DURING INFUSION may need to be regulated to a level lower than the vacuum pump is capable of. This particularly applies to resins containing volatile solvents which can boil under vacuum. Both polyester and vinyl ester resins should usually be infused at less than maximum vacuum.
8. When thermosetting resins are used, a period of time must be allowed for the resin to CURE after the laminate has been completely infused with resin. This time may vary from a few minutes to a few hours depending on the resin system and the size of the part.
9. Once the resin has solidified, the bag and the part can be removed from the mould. The resulting part will be a homogenous structure, with all components bound together within the resin matrix.

Feedback or queries on this note?

We are keen to improve the accuracy and value of Vacman's Notes. If you have any feedback or queries regarding this note, or would like to suggest new topics to be covered, Vacman would be pleased to hear from you! Please email Vacman@vacmobiles.com.

Vacmobiles.com™
Better vacuum systems for better composites

16 David McCathie Place, PO Box 78, Silverdale 0944, New Zealand
Email: info@vacmobiles.com Website: www.vacmobiles.com
Tel: +64 9 426 4095 Fax: + 64 9 426 1902