GUIDE TO RESIN INFUSION

Introduction

Vacuum resin infusion is a sophisticated technique for manufacturing high performance, void free composites even on large or complicated moulds. The process is ideally suited to the manufacture of carbon fibre composites and is widely used by professional manufacturers for the production of carbon fibre body panels such as bonnets and by marine manufacturers in the production of boat hulls.

In resin infusion, reinforcement is laid into the mould 'dry', i.e. without any resin, and then enclosed in a specially configured stack of bagging materials (such as peel ply, infusion mesh and bagging film) before being subjected to vacuum pressure using a composites vacuum pump. Once all the air has been removed from the bag and the reinforcement has been fully compressed under this pressure, liquid epoxy resin (mixed with hardener) is introduced to the reinforcement through a pipe which then infuses through the reinforcement under the vacuum pressure. Once the resin has fully infused through the reinforcement, the supply of resin is cut off (using a line clamp) and the resin is left to cure, still under vacuum pressure.

Advantages of Resin Infusion

Resin infusion, when done correctly, can produce parts of incredible strength and quality of appearance. The combination of vacuum pressure along with carefully placed vacuum consumables (such as peel-ply and infusion mesh) mean that the finished composite will have absorbed resin at the optimum resin-to-reinforcement ratio. This helps to avoid resin-rich composites or variations in performance which are inevitable with traditional wet lay manufacture.

The resin infusion process also eliminates some of the problems that can blight wet lay composites, such as air voids (caused where the reinforcement has bridged around tight corners) and tiny air bubbles caused by air trapped within the laminate.

The quality of epoxy 'infusion resins' means that resin infused parts can be made with strength to weight ratios that can rival parts made using pre-impregnated (pre-preg) reinforcement systems.

Starter Kit Contents

Not included in main kit:

(can be purchased as optional extra)

EC4 Vacuum Pump

IN2 Infusion Epoxy

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Components/Materials	Use
EC4 Composites Vacuum Pump (option to add this to starter kit)	Electric powered vacuum pump capable of very high vacuum pressure (99.98% vacuum). This pump creates the vacuum pressure that draws all of the air out of the vacuum bag and maintains this vacuum pressure throughout the cure cycle of the composite.
Resin Catch Pot & Liners	The catch pot sits between the composite and the vacuum pump and prevents any excess resin from the composite being drawn down the vacuum tube and into the pump. The catch pot can be lined with removable liners so that any resin caught by the pot can be easily discarded after the process is complete.
Vacuum Gauge (on catch pot)	The vacuum gauge shows the level of vacuum in the system and is invaluable in identifying when there are tiny leaks in the vacuum bag. Infusion should never be started until the whole system is maintaining full vacuum (at least 99.9 on the vacuum gauge).
Line Clamp	The line clamp is used to close off the flow of resin from the feeder pot into the bagged composite. The tube is usually clamped just before the resin flowing into the composite reaches the end of the reinforcement (to allow for lag in the system).
Silicone Resin Infusion Connector	The connectors form the join between the vacuum hoses and the vacuum bag. Silicone connectors are used (instead of metal through-bag connectors) because they will become coated in resin during the infusion process. By being silicone, resin can easily be cracked off them after the process is complete and used again.
Vacuum Hose	The vacuum hose connects the vacuum pump, catch pot and resin feed pot to the bagged composite.
Vacuum Bagging Film	This film is used to create the outer vacuum bag from which the air is evacuated by the pump. The film is tear resistant and sticks extremely well to the bag sealing tape.
Peel-Ply	This thin woven fabric is the first removable layer between the composite and the vacuum bag and helps to prevent the consumables from sticking together. Peel-Ply also creates a surface that, when removed from the composite (after the process is finished) provides a textured surface that is particularly well suited for bonding.
Resin Infusion Mesh	Infusion mesh is a plastic mesh pattern designed to promote resin flow during the infusion process.
Resin infusion Spiral	This plastic spiral tube is used to provide a very free-flowing channel through which the resin is distributed near the point where the resin is first fed into the composite. Resin flows freely through the centre of the spiral tube, but just as easily out of the spirals in the side, allowing resin to be supplied all the way along an edge of the composite.
Vacuum Bagging Sealant Tape	This special sticky, gum-like tape is used to create perfect seals between the two faces of a vacuum bag (when envelope bagging) or between the vacuum bag and mould's flange when half-bagging a mould.
Epoxy Infusion Resin (additional option for kit)	The resin infusion process requires special low viscosity resin. Unlike polyester resins (which tend to 'boil' under the vacuum) epoxy infusion resin is ideally suited for this process.

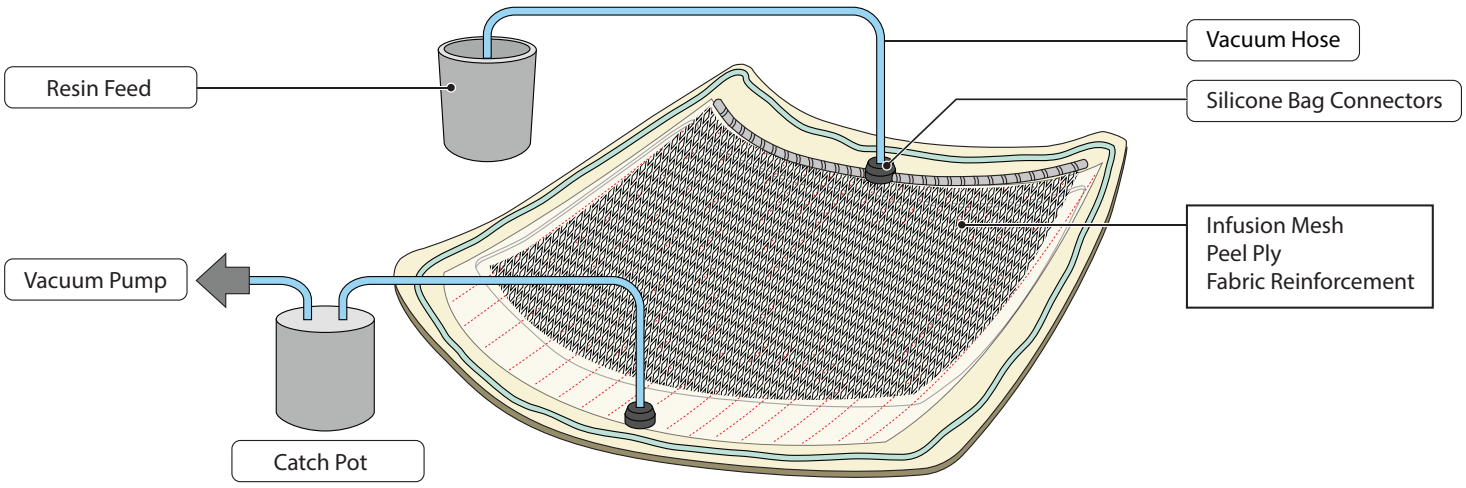
Setup

The key to successful vacuum resin infusion is having all the right equipment and preparing everything in advance.

Once the epoxy infusion resin has been mixed with its hardener, if anything goes wrong it is generally too late to do anything about it. Any problems such as running out of resin, loosing vacuum or having a leak in the bag will almost certainly result in the part being ruined. This means that for the first few attempts, methodical planning is essential.

Having said this, the nature of resin infusion is such that correctly following the procedure should produce perfect parts every time.

Basic configuration



There are many alternative configurations to the above that can be used for resin infusion. The above configuration, however, is quite typical and makes a good starting point.

Suitable Moulds

Before you can start the resin infusion process, the first step is to have a suitable mould. A mould suitable for resin infusion is much the same as a mould that would be used for conventional wet-lay fibreglass, with a couple of important distinctions:

Mould surface

The best infusion resins are epoxy, therefore it is important that the surface of the mould that will be used for infusion is also made from a compatible material; epoxy tooling gel, epoxy resin coating and our Uni Mould system would all be good options.

Mould surfaces made from polyester are likely to result in epoxy resin parts sticking to the mould, destroying both the part and the mould.

It's not recommended but if you have no other option than a mould made with a polyester gel coat for your infusion project, one solution is to use a PVA mould release agent, rather than mould release wax or chemical release agent. PVA will create a sufficient barrier between the polyester mould surface and the epoxy part to endure that the part will release from the mould. The disadvantage of this method is that PVA needs to be cleaned off the mould and re-applied each time it is used, additionally the part will need quite a bit of polishing to remove the smear pattern that PVA produces.

Mould flanges

The resin infusion process requires the mould to have some additional flange area around the perimeter of the part. This flange area is used to place the vacuum connectors, resin feed connector, infusion mesh and resin flow channels. It is sometimes possible to find enough space on existing moulds to position these infusion specific items but if there isn't room you will need to remake or extend your moulds.

Safety Information

Infusion epoxy resin, once mixed with its hardener is exothermic. If large amounts of mixed resin remain in the feed pot or accumulate in the catch pot, the resin can become very hot indeed. In extreme circumstances, the resin can actually start smoking as it reaches very high temperatures. This will only happen where the resin is accumulated in one place, and only where too much resin has been prepared.

During your first few infusion projects, it is important that you keep an eye out for large amounts of excess resin either remaining in the feed pot or accumulating in the catch pot. Whilst there isn't much that can be done about excessive resin in the catch pot (without breaking the vacuum and spoiling the part), excess resin in the feed pot can be dispensed into smaller containers or otherwise dispersed to reduce the chances of this becoming too hot. This should only ever be done once the infusion process is complete and the resin feed line has been clamped-off.

Step by Step Instructions

Before you start

The mould surface should be prepared using your favoured release agent. PVA, wax and chemical release agents are all suitable although you should ensure that if a chemical release agent is used that it is compatible with or better still, designed for epoxy resin systems.

The key to successful resin infusion is preparation. Before actually starting your project, ensure that you have read through these instructions in advance. Make certain that you have everything you need and already have your patterns cut to size.

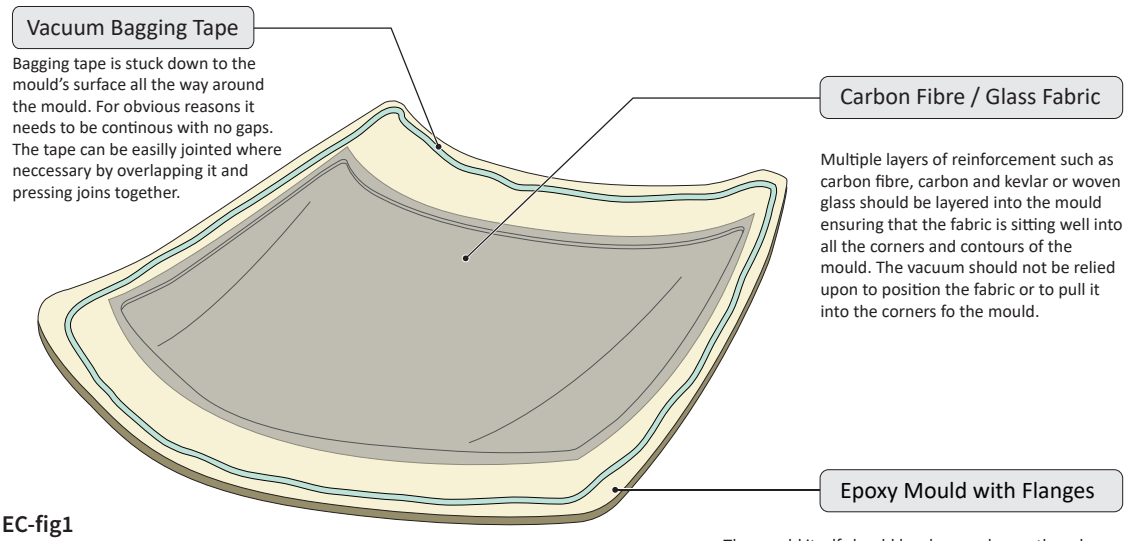
If a gel coat is required on the part then this should be applied and allowed to cure before proceeding.

Preparation

1. Prepare the mould surface & add bagging tape (see fig.1)

If you will be allowing the infused part to cure at ambient temperature then conventional mould release wax or CR1 are suitable release agents for the mould. If you intend to accelerate the cure with elevated temperature (see 'page 10') then wax is not suitable and a temperature tolerant chemical release agent such as CR1 should be used.

Prepare the mould surface according to the guidance that accompanies your chosen release agent. Remember to cover the entire surface of the mould and flanges with the release agent as you won't be able to control where the resin goes once the infusion starts. This is also the ideal time to add the vacuum bagging tape to the mould flanges without the risk of stray fibres compromising the airtight seal. For mouldings with cavities and other detail you need to factor in extra bagging material that will conform to these areas. To prevent the bag from pulling tight on the sealing tape, pleats need to be added to the tape to allow for this additional material.



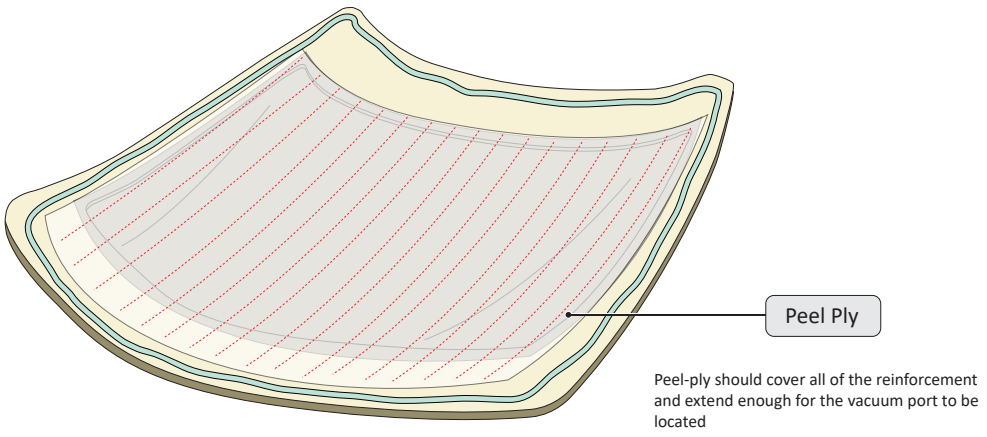
EC-fig1

2. Cut and position the reinforcement (see fig.1)

Cut your reinforcement to the appropriate size for your moulding. Where possible, always try to make the part using a single piece of fabric for each layer. A typical carbon fibre product will use anywhere between 2 and 6 layers of carbon fibre. If you're unsure how many layers to use, 3 layers is often right for a small, light part. Ensure you cut the fabric large enough that it extends beyond all the edges of where the trimmed part will come to. Position the multiple layers of fabric into the mould (you can position them all at once). In more complicated moulds; particularly those with steep sides or multiple contours, it is sometimes necessary to use spray-tack to hold the laminate against the mould surface and hold subsequent layers of reinforcement to each other. Over use of this will remain visible on the surface ply so use sparingly, for subsequent layers this isn't an issue and can be used as required.

3. Add the Peel-Ply layer (see fig.2)

Peel-ply is the first layer of the infusion 'bagging stack' and is a removable barrier that is peeled off the finished part, leaving a relatively consistent surface that is also ideal for bonding. Peel ply is usually applied in one single layer (although multiple pieces can be used), positioned to completely cover all areas of the reinforcement. The peel-ply should extend past the reinforcement far enough on one side so that the vacuum port can be positioned.

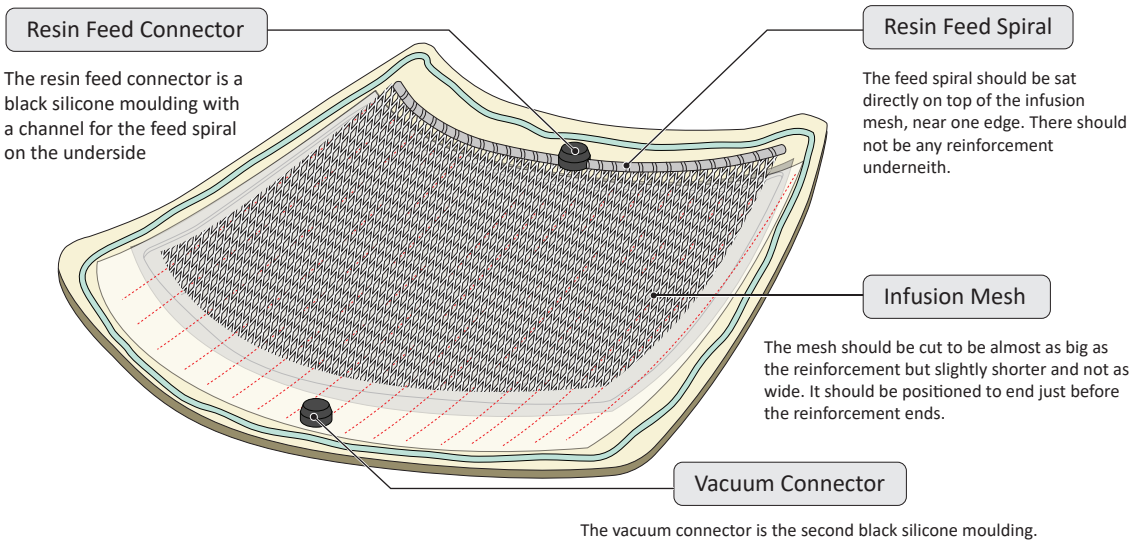


EC-fig2

4. Add the Infusion Mesh (see fig.3)

The infusion mesh (also known as 'flow media') is used to ensure that the resin can flow from the resin feed line (and spiral tube) freely through the laminate. The shape of the mesh means that even under total vacuum, there are still gaps through which the resin can flow.

The infusion mesh is applied in a single layer (although it won't affect anything if multiple pieces are overlapped where necessary). It should be cut just smaller than the size of the reinforcement.



EC-fig3

5. Position the resin feed spiral (see fig.3)

The resin feed spiral is spiral wrapped plastic tube that is used to improve the flow of the resin from the feed tube into the laminate. Resin will be dispersed along the full length of the spiral. The standard configuration is to position the spiral all the way down one side (the side where the feed tube will be positioned). This means that the resin is quickly distributed along one side of the mould and then advances more evenly across the width.

It is essential that the resin feed spiral is positioned directly over the infusion mesh. This ensures that the resin can flow easily from the spiral into the mesh.

In larger or more complicated infusions, multiple resin feed lines and more considered positioning of the resin feed spiral is sometimes required. This is not likely to be necessary for most projects, however, if you find that some areas of your laminate wait an excessively long time for the resin to reach them you can improve resin flow to those areas with some additional feed spiral.

Secure the resin feed spiral in position using a couple of small pieces of release tape/masking tape.

6. Position the resin feed connector (see fig.3)

The resin feed connector is one of the black silicone connectors. It is into this channel that the resin feed spiral goes, allowing resin to flow from the feed tube, through the connector and into the spiral.

Position the resin feed connector in the centre of the resin feed spiral. Press the connector down onto the spiral so that the spiral tube runs through the bottom of the connector.

7. Position the Vacuum Connector (see fig.3)

The vacuum connector is the other black silicone connector; it allows free airflow from the connector into the material underneath even under total vacuum.

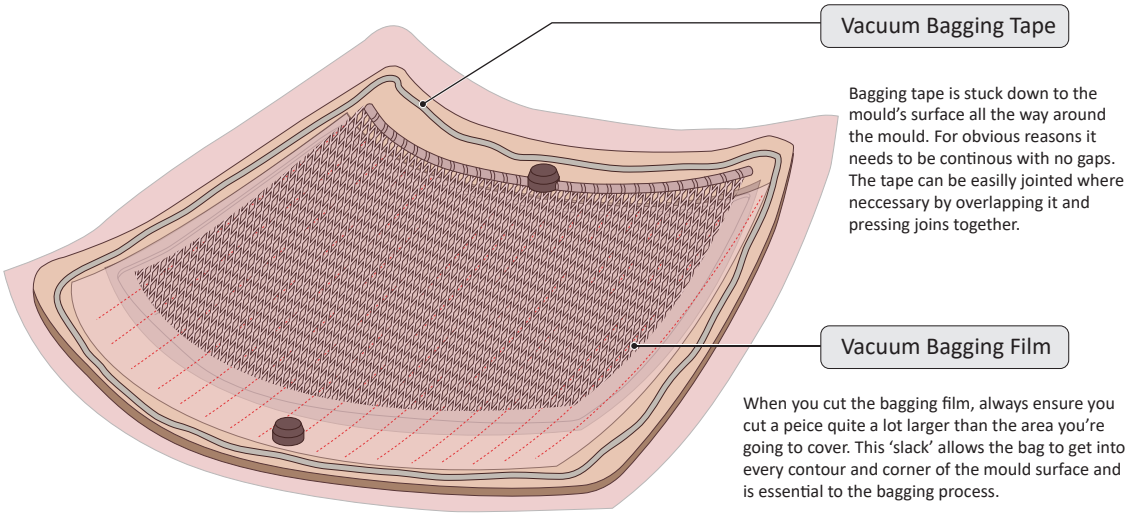
Position the vacuum connector on top of the peel ply at the opposite side of the mould to the resin feed spiral. The connector should sit on top of the peel ply in an area beyond where the reinforcement ends.

8. Position and tape down the Vacuum Bag (see fig.4)

It's now time to enclose everything within the vacuum bag. When doing the bagging it is absolutely essential to ensure that there is sufficient bagging film to get into all the shapes and contours of the mould. Any 'bridging' of the vacuum bag where it doesn't get right into the corners of the mould will result in resin-rich areas, reducing the strength and quality of the finished part.

Cut a piece of bagging film (the red plastic film) that is plenty large enough to cover an area about 50% larger than your mould area. Starting in one corner, peel the backing paper off some of the bagging tape and press the corner of the bagging film down onto the exposed tape. Move around the edge of the mould, removing backing paper from the tape and sticking down the bagging film as you go. Don't be tempted to remove all the backing paper from the tape; this is likely to result in the bag sticking to the tape before you've aligned in properly.

As you stick the film to the tape, be as careful as possible to do so without having any wrinkles or folds in the bag. Press down very firmly and use your fingers to 'massage' the film and tape together to create an airtight seal. If you end up with leaks in your finished bag (which we'll test for later) then it is likely that wrinkles or folds in the bagging film where it contacts the tape will be the cause.



EC-fig4

8.1 Alternative method - envelope bag

In resin infusion it is most common to apply the tape to the flange around the edge of the mould, whereby the mould makes one side of the 'vacuum bag', with the bagging film forming the other side (as described above). If this isn't possible then the bag can be wrapped around the entire mould, front and back, in which case the bagging tape would be applied to one half of the bag rather than to the surface of the mould. This may be preferable if the flange is not made from smooth, unbroken gel coat or is too small to achieve a good airtight seal to the mould's surface.

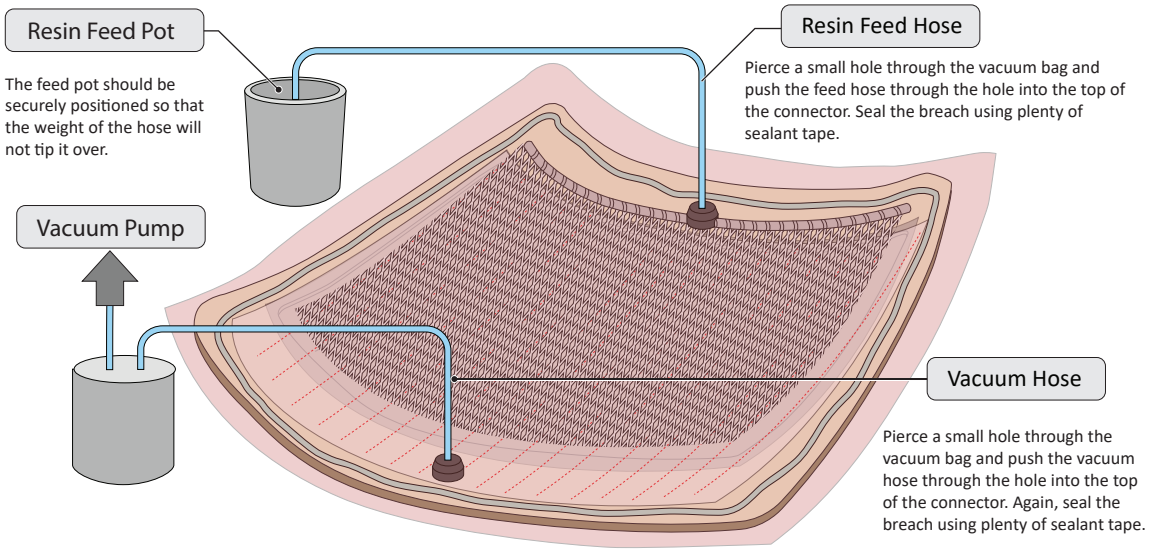
9. Connect and seal the resin feed hose (see fig.5)

With all the bagging stack and reinforcement sealed within the vacuum bag, you're now ready to 'breach' the bag to connect the resin feed hose. Using a pair of scissors or a knife, make a small incision in the vacuum bag directly above the silicone resin feed connector.

Cut a length of the clear PVC hose long enough to run comfortably from where you will position your resin feed pot to the resin feed connector on the vacuum bag. When you cut the hose, do so at an oblique angle (such as 45º) so that it is impossible for the tube to accidentally be sealed against the bottom of the mould.

Taking the end of the hose with the oblique cut, push the hose through the small hole in the vacuum bag and into the hole in the top of the resin feed connector. Ensure that the tube has gone all the way into the connector.

Seal the tube to the bag by wrapping a ring of the bagging tape around the tube where it meets the bag. Press firmly to ensure the tape has made an airtight seal.



EC-fig5

10. Connect and seal the Vacuum Hose (see fig.5)

Repeat the process from the previous step, this time using another length of PVC tube that will connect the catch-pot to the silicone vacuum connector at the opposite end of the part to the resin feed. Cut the tube at an angle, cut a small hole in the bag, push the tube through and seal the tube to the bag using some more tape.

11. Set-up the resin feed pot (see fig.5)

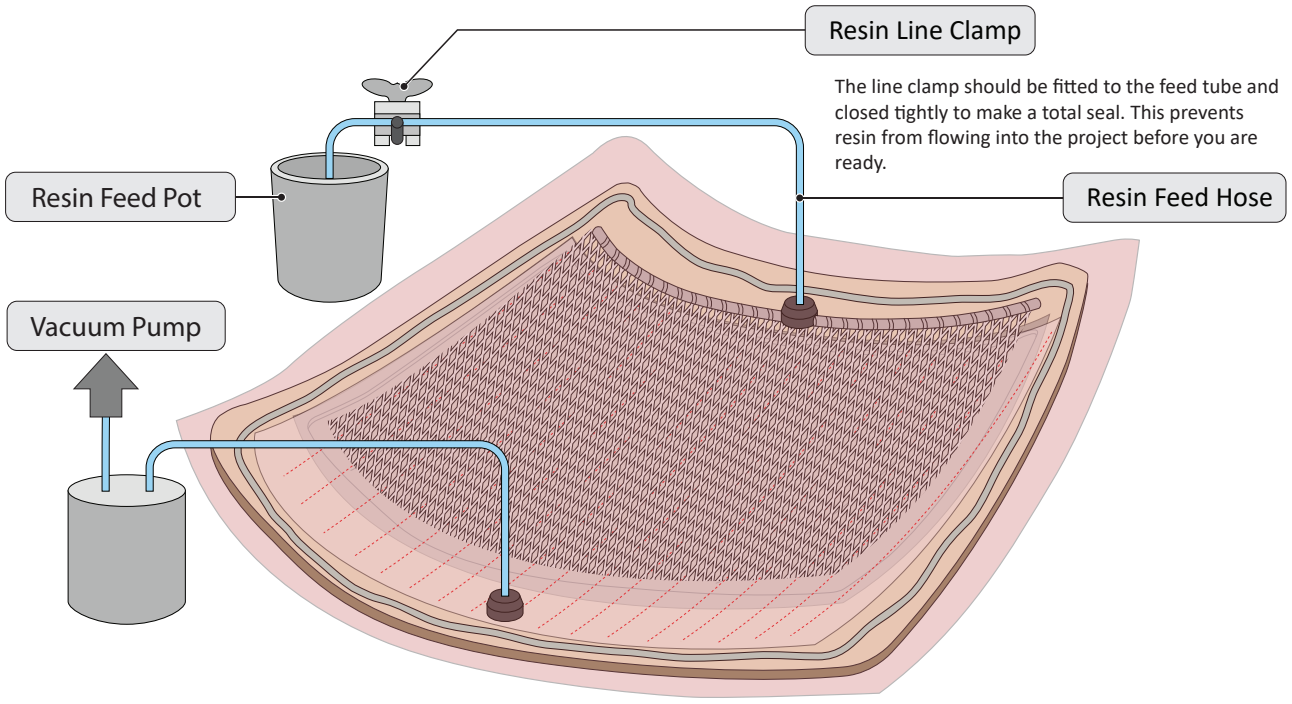
The resin feed pot should be securely positioned near the mould. It is absolutely vital that the resin feed pot does not fall over during the infusion and allow air to be drawn in; if it does, the part will certainly be ruined. Position the resin feed hose inside the feed pot so that the tube reaches all the way to the bottom of the pot. If necessary, tape the hose to a mixing stick and secure to the side of the feed pot.

12. Connect the Vacuum Pump and catch-pot (see fig.5)

Connect the other end of the vacuum hose to one of the push fittings on the resin catch-pot. Push the hose on firmly to ensure an air-tight seal. Next, cut a length of 8mm silicone tube, sufficient to run from the vacuum pump to the other barb connector on the catch-pot. This tube can be as long as you need and will not be spoiled by the infusion process (meaning it can be re-used indefinitely).

13. Clamp the resin feed line (see fig.6)

Position the line clamp tube near to the start of the resin feed tube and turn the wing-nut or thumb screw to clamp the pipe shut. Ensure that you close the pipe properly to create an airtight seal.



EC-fig6

14. Switch on the Vacuum Pump

With everything in place, we're now ready to test the vacuum. If you've not already done so, ensure the vacuum pump is filled with the appropriate amount of vacuum pump oil and connect it to the mains power supply. Switch on the vacuum pump.

15. Evacuate the air and adjust the Vacuum Bag

As the air is removed from the vacuum bag you will see the bag tighten around the mould surface. As this happens you should move the bag around and position it so that you move 'spare' bagging film into the areas of the mould which need it. This process is essential to all vacuum bagging processes (resin infusion, standard vacuum bagging and even pre-pregs) so give this step plenty of attention.

As the bag begins to become reasonably tight (not fully evacuated but not slack either) temporarily switch off the vacuum pump. This will allow you all the time you need to reposition the bag, working wrinkles towards where they're needed and ensuring that no-where on the mould is the vacuum bag 'bridging' a gap.

During your first few infusion projects, it is possible that you will underestimate the amount of bagging film necessary for your mould. If this happens you will find out at this stage because the bag will be 'bridging' across certain points of the mould and there will be no amount of re-positioning that can fix it. In the unfortunate event that this happens, you should stop, remove the bag (and tape) and do the bag again. If you proceed with a bag that is too small, your finished part will suffer greatly.

16. Test the vacuum

Switch the pump back on and finish evacuating the bag. You should see the needle on the vacuum gauge begin to rise. Leave the pump on and wait as the needle approaches full vacuum. Keep adjusting the bag if necessary to ensure there are no 'bridges'.

After a few minutes the vacuum gauge should read somewhere very near to 100%. Because of variations in atmospheric pressure and calibration of the gauges the needle might not point precisely to 100% vacuum even when full vacuum is being drawn.

If the seal isn't total, work your way around the bag, pressing the bag hard against the gum tape until it is.

17. Drop Test

Another good practice is to perform a drop test, this will determine if there are any tiny leaks in the system that will cause loss of pressure. To perform the drop test clamp the line between the catch-pot and the part to isolate the vacuum bag, then switch off the pump leave for 10-15 minutes. Once this time has passed turn on the pump briefly for a few seconds to ensure that the catch pot is still at full vacuum before turning it off again. The line clamp can then be removed and the gauge on the catch pot monitored. Any movement on the dial will indicate a leak in the bag which will need to be addressed before the infusion can take place.

The Infusion

Only once your vacuum bag is perfectly sealed (with the gauge reading approximately 100%) should you embark on the infusion itself.

1. Gauge the correct amount of resin

The amount of resin that your project will need will vary upon its size and the amount of reinforcement you have used; more layers of reinforcement will require more resin.

With resin infusion you are normally looking to achieve a 60/40 fibre/resin ratio. For example, every 100grams of cloth you will need 66 grams of resin. The reinforcements are listed by weight e.g. carbon fibre 2/2 twill 200gsm. The 200gsm refers to the actual weight of the fabric in grams per square meter, so 1 square meter of this cloth will need 133g of resin to achieve the 60/40 ratio. You also need to account for the amount of resin used by the mesh and peel ply which is 700grams per square meter of laminate, regardless of thickness. Another 100grams of resin will be required by the feed lines and in the bottom of the resin pot.

This can be expressed in the following equation;

$$Resin\ Consumption\ in\ grams = \left(\frac{Fibre\ Weight\ per\ m^2}{1.5} + (700 \times\ surface\ area\ m^2)\right) + 100$$

Use the table below to calculate approximately how much resin you should mix to ensure you have enough resin for the infusion:

Fabric 200gsm	Number of Plys	1	2	3	4	5	6	7	8
	Total Fabric Weight	200gsm	400gsm	600gsm	800gsm	1000gsm	1200gsm	1400gsm	1600gsm
Surface Area	0.1m²	303g	437g	570g	703g	837g	970g	1103g	1237g
	0.2m²	373g	507g	640g	773g	907g	1040g	1173g	1307g
	0.3m²	443g	577g	710g	843g	977g	1110g	1243g	1377g
	0.5m²	583g	717g	850g	983g	1117g	1250g	1383g	1517g
	0.8m²	758g	892g	1025g	1158g	1292g	1425g	1558g	1692g
	1.0m²	933g	1067g	1200g	1333g	1467g	1600g	1733g	1867g
	1.3m²	1108g	1242g	1375g	1508g	1642g	1775g	1908g	2042g
	1.5m²	1283g	1417g	1550g	1683g	1817g	1950g	2083g	2217g
	2.0m²	1633g	1767g	1900g	2033g	2167g	2300g	2433g	2567g
	2.5m²	1983g	2117g	2250g	2383g	2517g	2650g	2783g	2917g
	3.0m²	2333g	2467g	2600g	2733g	2867g	3000g	3133g	3267g

2. Mix the Infusion Resin and add to the feed pot

Once you have worked out approximately how much resin is required, you next need to calculate the right ratio of resin to hardener and mix the resin.

The IN2 epoxy infusion resin needs to be mixed at a ratio of 100 parts resin to 30 parts hardener. As with all resins, it is important that the correct ratio is accurately measured and thoroughly mixed.

Use a set of digital scales to mix the correct ratio of resin to hardener. Mix the resin in a container other than the resin feed pot and then pour the mixed resin into the resin feed pot. This will greatly reduce the risk of any unmixed resin (usually clinging to the sides of the mixing pot) from being drawn into the infusion.

3. Unclamp the resin feed line

With the vacuum pump still running, gently start to unscrew the wing nut on the resin feed line clamp. As you loosen the screw you will immediately see resin start to be drawn down the feed line and into the infusion. Unscrew the clamp all the way to ensure there is no restriction to the flow of resin into the infusion.

4. Monitor the infusion and clamp the resin feed line once completed

Depending on the size and shape of the part, the layout of the feed spiral and the amount of reinforcement used, the resin will take somewhere between a few minutes and an hour to infuse fully through the part. Once the resin front has reached all of the reinforcement farthest away from the feed pot, the feed and vacuum line can both be clamped off. In some scenarios, for an improved resin:fibre ratio the resin feed line can be clamped off prior to the vacuum line, care must be taken to ensure this isn't done too early or the laminate will fail to fully infuse. This method will reduce the quantity of resin in the part and lower the overall weight, there is however an increased chance of pinholes and other defects forming on the surface as the laminate becomes more resin lean.

Improved cosmetic finish

In some situations where a high quality cosmetic finish is desired, or where pinholes and voids have been problematic, you can clamp the vacuum line BEFORE the resin feed to allow a little extra resin into the part. In these cases, you would allow the resin to reach the vacuum line then clamp it. Leave the resin feed line open from anywhere from 30 seconds to a few extra minutes allowing a little more resin into the bag, then clamp the resin line. You can adjust the extra time you leave the feed line open dependent on results.

Note: If lots of excess resin is drawn into the catch pot the resin may start to exotherm significantly and could start to smoke. If this happens, there is nothing you can do. Keep an eye of the catch pot and wait for the exotherm to die down.

5. Continue to monitor the infusion.

With both the resin feed/vacuum line clamped and the part fully infused there is nothing more to do other than wait for the resin to cure. Because excessive amounts of mixed resin in one place can exotherm dramatically, you should dispose of any resin in the feed pot and continue to keep an eye on the resin in the catch pot if there have been a significant amount pulled through.

6. Elevated temperature cure

The epoxy infusion resin responds very well to elevated temperature cure (curing in a composites oven or other warm environment). Although certainly not a requirement, curing at an elevated temperature can dramatically shorten the curing time (to only a couple of hours) and improve the temperature tolerance and strength of the finished part. Use the table below to see how cure temperature affects cure time:

Temperature	20°C	40°C	60°C	80°C	100°C	120°C
Cure Time	24hrs	11hrs	6hrs	4hrs	2hrs	1.5hrs

If you intend to cure the part at elevated temperature whilst still in the mould, ensure that your mould material is able to withstand the elevated temperature and that your release agent is suitable (mould release wax, for example, will melt and the part might stick to the mould). As an alternative to curing at elevated temperature in the mould, you can allow the part to cure fully at room temperature, remove it from the mould and then cure the part in an oven or warm environment. This process is known as post curing.

Whilst it does reduce the cure time by a significant amount, curing at elevated temperatures does pose the risk of the resin overheating and an exotherm taking place. For large parts or thick parts with many layers, the lower risk option is to cure at room temperature for 24 hours then undetake a post cure, the recommended cycle for IN2 can be found on the technical datasheet.

7 .De-Moulding

When the part is fully cured the vacuum bag can be cut away from the mould. In some cases you may choose to keep and re-use sections of the vacuum bag although the gum tape and infusion mesh are always thrown away. Generally speaking, leaving the part in the mould for a longer duration will allow the resin to cure further, this helps to reduce both distortion and surface print through from the fibres.

De-moulding steps:

- Cut the bagging film around the edge and remove.
- Remove the bagging tape from the edge of the mould (quick, sharp tugs are most effective)
- Remove the silicone connectors and crack any cured resin off them. They can be re-used.
- Remove and discard the infusion mesh
- Pull the peel-ply off the back of the part. This will take a little bit of force.
- Remove the part from the mould. Be careful not to damage the part or the mould, especially when force is required to remove the part.

Your part is now ready to be trimmed and finished. Easy Composites recommends Perma-Grit Tungsten Carbide tools for the cutting and shaping of carbon fibre parts.

Disclaimer

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