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How to use the Vacmobile End Vacuum Adjustment (EVA) valve

Benefits of an EVA valve in the vacuum applications in composites

While the vacuum processes in composites usually appear to be dry, the reality is that they are always "wet" to some degree. Unless the entire storage and work area is kept at zero humidity, one wet component is always water from atmospheric humidity. A small amount of water is inevitably absorbed into the reinforcement, into the mould and bag surfaces and other materials in the layup. When subjected to vacuum this absorbed water may be converted into a large volume of gaseous water vapour. Most resin systems, especially the ester resins, also contain solvents which vapourise under vacuum. Please refer to our Vacman's note "Vapour – the unseen enemy in composites" for more information about vapour related problems.

For vacuum pumps that can achieve an absolute pressure lower than the vapour pressure of the "wet" components inside the vacuum bag, the problem with vapour entering the pump is that the vapour will be compressed back into liquid as the pressure rises through the pump. This condensed liquid will contaminate the vacuum pump oil, leading to poor vacuum and, possibly, corrosion and wear.

From the laminate's perspective, the vaporisation of the "wet" components will cause two problems:

- Final evacuation will slow down, as the evaporation of liquid under vacuum results in a large gas volume that has to be pumped away.
- Vapour bubbles will form, leading to voids in the laminate. Unless given sufficient time to move to the vacuum pump, these voids will cause defects in the laminate.

Depending on the required laminate quality and the type of resin system being used, it would be ideal if the end vacuum (the lowest absolute pressure the pump can achieve) of the pump could be controlled so that either:

a) All "wet" components, including water, could be boiled out of the laminate (but without affecting the vacuum pump), or
b) All "wet" components could be left undisturbed so that vapour generation cannot occur.

Vacuum condition a) would normally be desirable for high performance laminates made from low vapour pressure resins such as epoxy. In condition a), a final absolute pressure in the range of 1 mbar to 10 mbar would typically be appropriate. Vacuum condition b) would normally be desirable for medium performance laminates made from high vapour pressure resins, such as polyester and vinyl ester. Depending on the catalyst used with these resins, the pump's lowest absolute pressure may need to be limited to somewhere between 100 mbar and 300 mbar to avoid solvent boiling.

Another situation where regulation of the vacuum pump's end pressure may be useful is when infusing with a low vapour pressure degassed resin, using the same pump for both stages of the process. In this duty, the degassing stage could be performed at a low absolute pressure (say, 1 mbar) and the infusion stage at a higher pressure (say, 10 mbar). While degassing should remove the bulk of the water vapour and other volatiles from the resin, some very small bubbles may remain. If the infusion stage pressure is raised, the residual bubble size will reduce in inverse proportion to the increase in pressure, in accordance with the Boyle's Law formula:

$$P_{(degas)} \times V_{(degas)} = P_{(infusion)} \times V_{(infusion)}$$

An EVA valve fitted to a suitable vacuum pump will allow the end vacuum of the pump to be regulated quite precisely (typically ±2 mbar) for any of the above applications. Please note that while the EVA valve appears to function much the same as the vacuum regulator fitted to Vacmobile resin traps, the two forms of control are quite different. When fitted to a VSV-20 vacuum pump, the EVA valve accurately controls the pump end pressure independently of atmospheric pressure at low absolute pressures between 0.5 mbar and 280 mbar, whereas the vacuum regulator on the resin trap is for the more approximate control of pressures between 100 mbar and atmospheric pressure.

Why we usually fit the EVA valve only to the VSV-20 vacuum pump

We began fitting the EVA valve to our Vacmobile systems in 2017, after thorough testing confirmed that the VSV-20 would be an ideal vacuum pump for our composite applications. We had been wanting to fit such a valve to our systems for some time but needed to wait until a 20 m^3/h (11.8 cfm) capacity, heavy duty, single stage vacuum pump that could achieve less than 1 mbar of absolute pressure with an open gas ballast became available. The VSV-20 is such a pump. The reasons the pump had to meet these particular requirements are:

- The bulk of our systems are single phase powered and 20 m^3/h is about the maximum practical pump capacity for 115 V/60 Hz power. Twenty five years of resin infusion experience had also shown us that this capacity was suitable for pulling down infusion bags as large as 100 m^2 (1,100 ft^2) in area. This covered the bulk of the applications for our systems, with larger bags simply being evacuated by multiple Vacmobiles.
- Pumps we had previously used were capable of ultimate vacuums in the 10 mbar to 20 mbar range. This was fine for most applications, but some customers infusing with low vapour resins were keen to have access to a higher vacuum (lower absolute pressure) capability. Customers wanting to degas resins such as epoxy prior to infusion or for impregnating electronics components were also seeking a higher vacuum capability. While there are many vacuum pumps available (including low cost refrigeration service pumps) that will achieve absolute pressures lower than 0.5 mbar, very few affordable vacuum pumps meet the next criteria.
- It is critical for the longevity of composites industry vacuum pumps that they be able to reach maximum vacuum (lowest absolute pressure) with some external air passing through the pump. This flow of air is needed to remove condensable vapours from the gas being sucked into the pump from the laminate. If these condensable vapours are not removed, they will be condensed into liquid inside the pump. As noted earlier, condensed vapours will contaminate the vacuum pump oil, leading to poor vacuum and internal corrosion. The cleaning flow of air entering the pump passes through a valve called a gas ballast valve. Hence our need for a vacuum pump that would achieve a high level of vacuum with the gas ballast open.

What the EVA valve looks like and where it is fitted

The EVA valve is a small, manually operated valve assembly fitted to a T above the vacuum connection to a VSV-20 vacuum pump. The assembly is illustrated in Figure 1 and its components are:

1. EVA valve
2. EVA valve inlet filter
3. Vacuum pump inlet connection
4. On/off valve
5. Absolute pressure gauge port

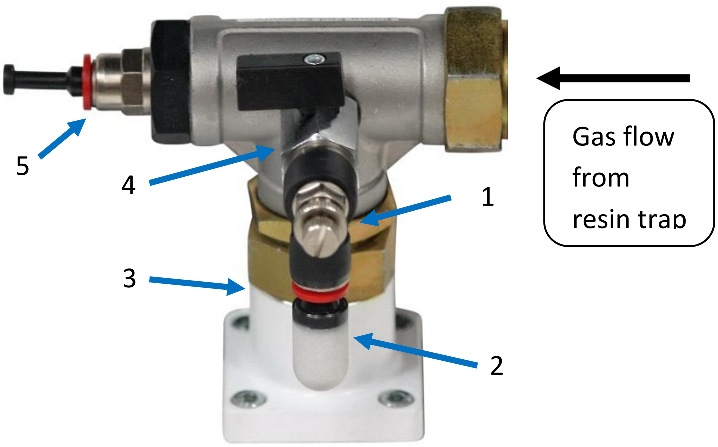

Figure 1

Using the EVA valve on the VSV-20 pump

The EVA valve (Pos. 1 in the illustration above) is a fine control needle valve. If fully wound in (by turning the knob gently clockwise) the valve will be closed. In normal use, it will not be necessary to close the valve fully and the valve will typically be left at the desired number of turns open. With the vacuum pump operating and the On/off valve (Pos. 4) open, a small air flow will pass through the EVA valve into the vacuum pump inlet. As long as the main valve isolating the pump from the resin trap is closed, the absolute pressure at the pump will settle at a pressure somewhat higher than the 0.5 mbar that the VSV-20 is capable of reaching with clean oil.

With the vacuum line to the pump is closed off, you will be able to regulate the VSV-20's lowest achievable absolute pressure to any pressure between the pump's lowest absolute pressure of about 0.5 mbar and a highest absolute pressure of about 280 mbar.

The absolute pressure at the pump inlet may be checked by connecting a calibrated absolute pressure gauge to the 8 mm (5/16") gauge port (Pos. 5). As long as the VSV-20 has reasonably clean oil, you can also use this connection for checking your absolute pressure gauge. Please see gauge calibration instructions later in this note.

The following recommendations provide the operating instructions for the EVA valve for particular composites applications, with the notes in red below applying to all applications.

In common with all vacuum pump applications where some vapour is likely to be involved, the vacuum pump should have been warmed up to normal operating temperature before use (after 30 minutes of running in an ambient temperature of at least 15^{0}C (60^{0}F), but allow an hour in cold conditions).

In all cases where the laminate (or whatever is being evacuated) is at an elevated temperature, recognise that vapour generation will be increased and evacuation will slow down. In severe cases, the evolution of vapour may be more than the vacuum pump can dispose of without oil contamination. If the pump oil should begin to discolour quickly, adjust the EVA valve so that the pump's end pressure (with the resin trap valve closed) is raised to approximately the expected vapour pressure at the laminate (please refer to the water vapour pressure chart in Figure 2, or to the solvent vapour pressure chart, if the resin supplier can provide this information). Reopen the resin trap valve and pump until the actual pressure drops to the end pressure you set the EVA valve to. You can now reduce the EVA valve pressure setting and continue pumping down to the desired end pressure. With large vapour volumes, this process may be too slow. If this is the case, the alternatives are to use a larger pump with an appropriate vapour pumping capacity, or to use a refrigerated inlet trap before the vacuum pump.

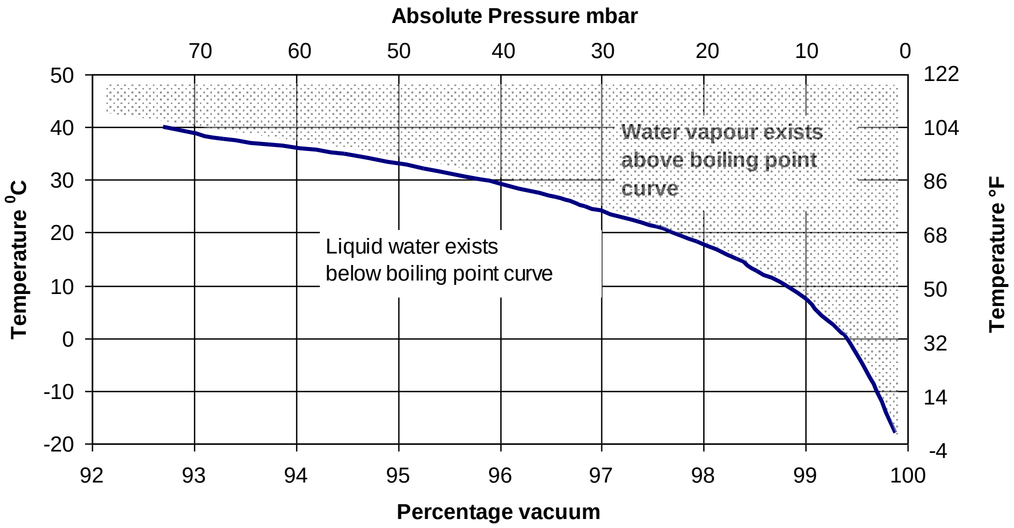

Figure 2, vapour pressure curve for water

Process A) High performance laminate infused with a LOW vapour pressure resin system that is NOT degassed first

Step A1 (optional) - You may wish to pre-set the EVA valve (Item 1 in Fig. 1) to about 10 mbar absolute or to some pressure above the pump's lowest end pressure, to provide a curing pressure somewhat above the infusion pressure (to reduce the size of any residual voids – see remark about Boyle's Law at the bottom of Page 1). Determining the optimum curing pressure may take some experimentation (unless in the laminate specification). With flat laminates the curing pressure could be quite high – perhaps as high as the maximum opening setting for the EVA valve. For complex laminates, where too high a pressure inside the bag might cause a change of laminate shape or thickness, the absolute cure pressure should be low. If the pressure used in Step 2 is 1 mbar absolute, 10 mbar absolute should provide a worthwhile void reduction and be safe in all cases.

We also recommend setting up the resin feed tube(s) so that the resin will be fed from the underside of the resin container(s), with tubing clamps or valves directly below the resin container. Setting up the resin feed in this way will ensure that no air is trapped in the resin feed line. Fully close the resin feed clamp(s), or valve(s) before applying vacuum.

Step A2 - Once the curing pressure (if any) has been set in Step 1, evacuate the laminate and leak test the bag and tubing with the On/off valve (Item 4 in Fig. 1) on the EVA valve assembly CLOSED. Note that the vaporisation of moisture in the laminate can stall the pumping down of the bag and a leak may appear to have developed. Before rushing to check for vacuum leaks, compare the absolute pressure that pumping has stalled at with the vapour pressure of water at the laminate temperature. Refer to Fig. 2. If about the same, be patient and allow the pump to remove the vapour.

Step A3 - Once any residual moisture in the laminate has been pumped away and when satisfied with the leak-tightness of the bag (see Vacman's Note "What is resin infusion?" for comments on leak-tightness), commence infusing at maximum vacuum with the On/off valve still CLOSED.

Step A4 – Following infusion and when the laminate is fully wetted out, you may want to OPEN the On/off valve. The pump will then maintain the previously set higher end pressure for void size reduction during curing.

Process B) High performance laminate infused with a LOW vapour pressure resin system that is to be degassed first, using the same pump for laminate evacuation, degassing and infusing.

(This assumes a reasonably small volume of resin that can be degassed and used in one batch. For large laminates and large resin volumes, it's best to degas with a separate pump.)

Step B1 – Pre-set the EVA valve to the desired infusion pressure, say 10 mbar absolute. Also set up the resin feed tube(s) so that the resin will be fed from the underside of the resin container(s), with tubing clamps or valves directly below the resin container. Setting up the resin feed in this way will ensure that no air is trapped in the resin feed line. Fully close the resin feed clamp(s), or valve(s) before applying vacuum.

Step B2 – Refer to A2.

Step B3 – Clamp off the vacuum lines between the resin trap and the vacuum bag. As long as the bag and piping system are leak tight, vacuum will be held under the bag.

Step B4 – Leaving the On/off valve on the EVA valve assembly closed, degas the resin at maximum vacuum. If less than 10 litres (2.6 US gallons) of resin, consider degassing on the way into a Vacmobile RT19 resin trap using the degas accessory. After degassing, carefully transfer the resin to the resin feed side of the laminate. (Try to avoid air entrainment by pouring the resin slowly.)

Step B5 – Open the On/off valve on the EVA valve assembly, unclamp the vacuum lines to the bag and resume pumping down the laminate (as the absolute pressure may have risen to some extent during degassing).

Step B6. – When satisfied that the absolute pressure at the resin trap is down to the infusion pressure, unclamp the resin feed line(s) and infuse the laminate.

Step B7 - Following infusion and when the laminate is fully wetted out, you may want to further OPEN the EVA needle valve (Item 1 in Fig. 1) to raise the pressure inside the bag to reduce the void size. Refer to comment in Step A1.

Process C Commercial quality laminate infused with a high vapour pressure resin such as most polyester and vinyl ester resins –noting that the high vapour pressure is likely to be caused by the cure initiator.

(For further information on the vapour pressure of typical initiators please refer to this website: http://polynovacomposites.blogspot.co.nz/2008/03/volitalization-and-vacuum-infusion.html)

Step C1 – Ask your resin and initiator suppliers to advise the vapour pressures of their materials over your ambient temperature range. Better still, ask them to supply vapour pressure versus temperature curves for the materials, as the actual temperature in the laminate is likely to rise above the ambient temperature, especially if the laminate is thick. Before making a production laminate we recommend infusing a test laminate representative of the thickest section of real laminate, following the remainder of the procedure below. Ideally, have an absolute pressure gauge connected to the EVA valve's gauge port and observe and record the absolute pressure at the pump.

As a starting point for this test laminate, set the EVA valve at the highest pressure shown on the resin or initiator vapour pressure curves for your ambient temperature and observe the test infusion closely. If you see large bubbles forming in the resin, OPEN the EVA needle valve further until the bubble formation ceases. If no significant bubble formation apparent gradually CLOSE the EVA needle valve until bubble formation occurs. Note the absolute pressure when the resin boiling occurs.

OPEN the EVA valve slightly to raise the absolute pressure about 10% above the observed boiling point and confirm this pressure increase causes the boiling to cease. If need be, OPEN the EVA needle valve a little more until you are sure resin boiling has ceased. Continue to observe the resin under the bag as curing takes place, as it is possible that you will have to further raise the pump absolute pressure when the resin exotherms. This step may seem a bit laborious, but it is necessary if you wish to avoid vapour bubble formation in the laminate, while still applying the maximum practical vacuum to the bag.

Step C2 – Evacuate the bag and leak test the bag and tubing. Since the absolute pressure applied during the infusion will be raised to avoid solvent boiling, you can leave the EVA On/off valve OPEN and perform the leak test at the pressure determined in Step C1. If the laminate has any sharp changes in shape you could pump down to a lower absolute pressure with the EVA On/off valve CLOSED to improve initial reinforcement consolidation, but the additional evacuation time will probably not be justified in most cases.

Step C3 - When satisfied with the leak-tightness of the bag commence infusing with the On/off valve OPEN so that the absolute pressure does not drop below the pressure arrived at in step C1.

Step C4 – Following infusion and when the laminate is fully wetted out, maintain the same absolute pressure arrived at in Step C1, but keep alert for vapour bubble formation under the bag in case the full-size laminate exotherms to a higher temperature than the test laminate did. If vapour bubbles occur, open the EVA needle valve further. If already at the maximum setting of the EVA valve, increase the curing pressure by opening the course vacuum regulator on the resin trap.

Using the EVA valve on a VSV-20 pump to check the zero position on an absolute pressure gauge

Our experience with a wide range of vacuum pumps over more than 30 years indicates that oil sealed rotary vane vacuum pumps (such as the VSV-20) will consistently reach close to their "as-new" end pressure under a blanked-off inlet condition. This is subject to some caveats, of course! These being:

- The pump is mechanically sound with vanes and bearings in good condition
- The pump oil is of the recommended type for the particular model – <u>and is in clean condition</u>
- The ambient temperature is "normal", say 10^0C to 30^0C (50^0F to 90^0F) and the pump has been running for at least 30 minutes.
- The gas ballast filter (if fitted) is clean. (The VSV-20 does not need a gas ballast filter, as the ballast air is taken from a protected position inside the pump's exhaust box)

Assuming these conditions are met, a VSV-20 will consistently achieve an end pressure with a blanked off inlet line of < 1 mbar.

For most composites applications, the VSV-20's low end pressure may be considered zero for absolute pressure gauge calibration purposes. To use The EVA valve's gauge port for calibration, follow this procedure:

1. Close the main resin trap valve above the pump's inlet connection
2. Remove the plug and connect your absolute pressure gauge to the gauge port on the EVA valve assembly (Item 5 on Fig. 1). This port will O-ring seal to a male gauge stem or gauge tube of 8 mm (5/16") diameter. This is a common stem size for compressed air fittings.
3. Close the On/off valve on the EVA valve assembly. (Item 4 on Fig. 1)
4. Note the pressure reading on your absolute pressure gauge. If your gauge reads in single digits of mbar, it should read either "0" or "1". If the reading is significantly different from 0 or 1 and your gauge has a zero adjust feature, reset your gauge to 0. Note that most absolute pressure gauges have separate adjustments for the zero and atmospheric pressure ends of the scale. Usually unimportant for most composite applications, if you do need to calibrate the atmosphere end of the gauge scale ask your nearest weather office for the current atmospheric pressure (noting that atmospheric pressure varies with elevation, and you may need an elevation correction as well).
5. After calibrating your gauge, remember to replace the plug in the calibration port and return the On/off valve on the EVA assembly to its normal position for your application. (If usually working with ester resins at relatively high absolute pressure, you would not want the pump to reach its usual 0.5 mbar end vacuum.)

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.

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Better vacuum systems for better composites

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