Technical Details

These notes cover the general technique for the manufacture of large scale tooling in both carbon and glass using ACG's LTF318 surface ply and ZPREG®260 series partially impregnated prepreg system (PIPS), which offer, with the inclusion of the syntactic resin films, an exceptionally high quality and accurate surface finish without the need for autoclave processing.

The technology offers significant advantages over conventional wet lay-up processing in terms of the time taken to manufacture tool skins, the size of mould tool that can be manufactured and the surface finish achievable.

Standard Materials

	Glass	Carbon
Surface Ply	LTF318B/GF1200/GF1100	LTF318B/GF1200/CF0300
Syntactic Ply	VTS263/GF1100 0.75mm	VTS263/CF0300 0.75mm
Bulk Ply	ZPREG264B GF0700/GF0700	ZPREG264B CF0700/CF0700

Table 1 - Standard Materials for Glass or Carbon VFT/VTM260 mould tools.

Typical tooling laminate schedule:

1 x LTF318B surface ply orientated at 0-90°
1 x Syntactic (VTS263) ply orientated at +/-45° (optional)
1 x ZPREG264B bulk ply orientated at 0-90°
1 x ZPREG264B bulk ply orientated at +/-45°
1 x ZPREG264B bulk ply orientated at 0-90°
1 x Syntactic (VTS263) ply orientated at +/-45° (optional)
1 x LTF318B surface ply (or VTM264 prepreg) orientated at 0-90°

For both the carbon and glass options, a tool skin thickness of approximately 6mm is achieved. For very large tools, or if increased stiffness is required, the number of bulk plies can be increased.

Notes:
1- The inclusion of the VTS263 syntactic films enhances the quality of the tool surface finish and gives excellent replication of all surface detail. On tools of relatively simple geometry, or for reasons of economy, it is possible to eliminate the syntactic plies.

2 - CF6300 12K 200gsm flat tow fabric can be substituted for CF0300 3K 200gsm in the surface and syntactic layers where the tool skin is of relatively simple geometry.

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Pattern Requirements

Typical patterns for large scale mould tools can be machined from tooling block, foams/modelling paste, fabricated from wood, etc. In all cases, the following general rules should be followed:

- The pattern should be manufactured so that the edge flanges are at least 50mm wider than would normally be used.

- If the pattern is fabricated from wood or machined from foam the surface must be sealed with a hard epoxy finish. Generally, within the marine industry, the pattern would be fabricated from wood, skinned with wet lay-up glass epoxy and then sprayed with epoxy filler and faired. It is recommended that a small test piece is also made at this stage and a small test tool skin cured on this to check compatibility with the release agent and epoxy filler. Some paints and primers, especially polyurethane paints, can react with epoxy prepregs and lead to the production of an under-cured surface on the tool skin. To guarantee stability during subsequent cure cycles, the pattern should be post-cured to a temperature 20°C (36°F) higher than the final use temperature.

  If in doubt, contact ACG for advice.

- The pattern should be vacuum-tight at the cure temperature (minimum 65°C [149°F]). Ideally, a vacuum leak test should be performed before the mould skin is manufactured. If the pattern is not airtight then this may result in a poor surface finish and porosity in the tool skin. A maximum recommended vacuum leak rate is 68mbar (2in Hg) in 10 minutes with the vacuum source turned off. Time spent ensuring that the pattern is vacuum intact will save time and effort repairing a pitted/leaking tool skin after processing. ACG can advise on techniques for testing and sealing patterns that leak.

- The oven must be tested to ensure it can produce a uniform temperature distribution. Large variations (+/-5°C [+/-9°F]) in oven temperatures can result in uneven flow and an erratic cure in the tool skin. Ideally, the vacuum leak test should be performed at the curing temperature. This test presents an ideal opportunity to check the oven's performance. Thermocouples should be taped to the vacuum bag and monitored during the initial ramp and the final dwell at the cure temperature.

- A suitable release agent should be applied to the pattern surface.

Laminating Schedule

- Remove the prepregs from frozen storage and warm up to room temperature before removing the protective polythene packaging. ACG recommends that the surface ply is thawed overnight. Initially, the surface ply will have minimal tack, but optimal levels of tack can be developed at room temperature.

- The surface ply should be overlapped at the edges by approximately 20mm (0.8in). In any tight corners/detail/flanges, etc, the surface ply should be cut to nestle into intricate details and then additional pieces laid up, overlapping the original pieces by approximately 20mm. This will prevent areas of bridging on sharp corners. If there are details, such as hatches, winch recesses, etc, the surface ply should be cut so that it can conform to the mould surface. Additional pieces of surface ply can be patched in as necessary.

  Note: It is imperative that the surface ply is laid up so that it extends at least 25mm (1in) beyond the subsequent syntactic and bulk ply layers. This extra surface ply material provides the air path from the tool surface into the breather. Failure to observe this will result in a pitted tool surface.

- The second ply to be laminated is the syntactic ply. This is a highly filled, 0.75mm (0.03in) thick resin film attached to a dry fabric, which is laminated resin side down. It is imperative that the syntactic is laid up at least 25mm (2in) inside the edge of the surface ply on the mould flanges, as stated in the note above.

- The syntactic ply is laid down at +/-45° orientation. The most effective way to apply the syntactic ply is to cut 50mm wide +/-45° strips and 300mm to 500mm (12 to 20in) wide 0-90 squares before commencing laminating; ACG offers a cutting service and can provide this material pre-cut if required. The strips and squares can be butt jointed or small (<5mm) overlaps used. The 50mm (2in) wide strip should be used in any sharp corners and to outline any areas of sharp details or complex geometry. Once all the corners/details have been laid up, the rest of the tool surface can be laminated with the squares orientated at +/-45°. Although it may appear time consuming to pre-cut the material into strips and squares rather than laminating straight from the roll, squares and strips are much easier to handle and minimise the chances of bridging or wrongly positioning the material.

- After the syntactic ply has been laid up with the surface ply (or just the surface ply if the syntactic layer is omitted), it is advisable to carry out a vacuum de-bulk. Perforated (P3) release film and lightweight breather should be used. A debulk of fifteen minutes at full vacuum (948 to 982mbar [28 to 29in Hg]) is recommended. It is important that the vacuum bag is a good fit, with no bridging of the corners or tension in any areas, thus ensuring that all detail will be accurately replicated in the final tool.

- The third, fourth and fifth plies are the ZPREG bulk plies. Depending upon the complexity and detail of the tool geometry, this can either be laid up from the roll or tiled in a similar manner to the syntactic film. Care is still required to prevent bridging in sharp corners. It is recommended that the material is cut and overlapped into sharp details so that the plies can move during

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consolidation and cure. The third and fifth plies should be laid up in a 0-90° orientation and the fourth ply at +/-45°.

- Depending upon the complexity of the geometry, additional vacuum debulks may be carried out. With care, it is possible to use the same vacuum bag, breather and release film for all debulks and then use a new vacuum bag for the final cure. Vacuum debulks may be performed after the surface ply, the first bulk ply and the third bulk ply.

- The final two plies are the second, balancing syntactic ply (at +/-45°) and a surface ply (at 0-90°). These should be laminated as detailed for the first two plies.

Bagging and Curing Procedure

- The recommended consumables pack for an oven/vacuum bag cure of a mould tool is as follows:

1. Apply one layer of perforated release film over the entire back face of the laminate, ensuring that it extends approximately 25mm (1in) beyond the edge of the lay-up.

2. Apply one layer of breather fabric over the entire lay-up. An additional mesh layer can be introduced on top of the breather to assist air bleed. Extra plies of breather may be fitted at vacuum breach positions.

3. Apply the vacuum membrane.

Caution:
High tack vacuum bag sealant tape has the potential to cause damage to mould tool flange areas during its removal. Therefore, customers are advised to check the adhesion characteristics of their sealant tape prior to use and determine if removal of the tape is likely to lead to delamination. Where the potential for damage exists, a less aggressive, lower tack sealant tape should be sourced or steps taken, such as using a mould sealer or applying a flash breaker tape, to minimise the risk of damage.

- The highest available vacuum, typically 982mbar (29in Hg), must be used during the cure. It is critical that the laminate is exposed to a high vacuum by checking with a vacuum gauge at the opposite side of the laminate to the position of the vacuum port. A vacuum drop test should be performed prior to curing the tool. The test must show no more than 68mbar (2in Hg) pressure loss within 10 minutes after the vacuum is removed.

- The recommended cure cycle for large mould tools is 16 hours at 65°C (149°F) with a ramp rate of no more than 20°C (36°F)/hour. The absolute minimum cure temperature is 65°C (149°F). If the oven is not particularly reliable or well controlled, it is sensible to increase the cure temperature to 70°C (158°F) to accommodate any potential cold spots.

- It is good practise to monitor and log, either automatically or manually, the temperature and vacuum levels during the cure cycle. For large area tool skins, i.e. >5m^2 (>6yd^2) the temperature should be monitored in more than one place. A minimum of one thermocouple for every 3m^2 (3.6yd^2) area is recommended. All thermocouples should be taped to the outer surface of the vacuum bag.

- Once cured the backing structure should be applied while the tool skin is still on the pattern. For a marine type tool, this will normally be a welded steel frame or a plywood structure. This should be bonded onto the tool skin with a flexible 'mastic' type adhesive such as silicone or polyurethane elastomer. This will prevent witness marks from the backing structure forming on the tool surface with repeated thermal cycling. Again, ACG can advise on these aspects.

Post-Cure

- The pattern it should be post-cured when it has been removed from the tool. It is recommended that the tool is post-cured to a temperature 20°C (36°F) higher than the final use temperature of the tool. For an 80°C (176°F) component cure temperature the tool should be post-cured to 100°C (212°F).

- A recommended 100°C (212°F) post-cure cycle would be:

  1. Ramp the temperature at a rate of 20°C (36° F)/hour to 100°C (212°F).

  2. Dwell for 4 hours.

  3. Cool at a rate of 20°C (36° F)/hour to room temperature.

Check List

The following check list will help achieve optimum results.

Pattern/Oven/Vacuum Requirements:

1. Has the pattern been manufactured with an edge flange 25 to 50mm (1 to 2in) wider than would normally be used?

2. Has the pattern and sealing paint been post-cured to a minimum temperature of 85°C (185° F)?

3. Has a test laminate been manufactured to test the compatibility between the epoxy/polyurethane paint, the release agent and the ZPREG260 system?

4. Has a vacuum drop test been performed to ensure that a leak rate of less than 68mbar (2in Hg) over 10 minutes is achievable? This must be performed with the vacuum system removed.

5. Has the oven been thermally mapped to ensure a uniform temperature profile?

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Laminating Requirements:

1. Have the laminators been fully briefed in the use of the ZPREG tooling system?
2. Has all the correct information (data sheets, etc.) and control paperwork been put in place?
3. Has the surface ply developed an optimal level of tack?
4. Has the surface ply been cut to extend 25mm (1in) past the rest of the laminate on the tool flanges?
5. Has the surface ply been cut, tailored and overlapped into sharp details?
6. For complex corner details, has the syntactic ply been cut into 50mm (2in) wide +/-45° strips?
7. Has the syntactic been cut into 300mm to 500mm 0-90° squares to facilitate laminating?
8. Debulk of surface and first syntactic ply.
9. Have the ZPREG bulk plies been cut and tailored into sharp corners to eliminate bridging?
10. Are additional debulks to be carried out?

Curing Requirements:

1. Has a perforated release film been used?
2. Have the breather felt and release film been cut and tailored into sharp corners to eliminate bridging?
3. Has the vacuum bag been applied with sufficient loose bag and tucks to prevent bridging and tension in sharp corners?
4. Has a minimum of 982mbar (29in Hg) vacuum level been achieved and will this drop at a rate less than 68mbar (2in Hg) during ten minutes when the vacuum source is isolated?
5. Can a minimum cure temperature of 65°C (149°F) be achieved over the entire tool surface?
6. Is the vacuum level and temperature distribution being monitored and recorded during the cure, and is this being checked in enough locations to instil confidence that the entire part is at the correct vacuum and temperature levels during the full cure cycle?

Post-Cure

1. Has maximum use temperature been established and tool post-cured to 20°C (36°F) above this temperature?