ADVANCED COMPOSITES
Processing information

TENCATE AmberTool®

COMPOSITE TOOLING PREPREGS

TENCATE

TABLE OF CONTENTS

PRODUCT PORTFOLIO

TenCate AmberTool®	Resin	T_g (onset)*1	Min cure temp	Typical cure time and temperature*2	Tack life (days)	Description	Aerospace	Industrial	Motorsport	Automotive	Marine
HX40	Epoxy	203°C (397°F)	50°C (122°F)	12 hours at 65°C (149°F)	8	Large tooling applications	○				
HX42	Epoxy	200°C (392°F)	50°C (122°F)	8 hours at 60°C (140°F)	5	Proven system for aerospace	○	○	○	○	
HX44*3	Epoxy	188°C (370°F)	50°C (122°F)	10 hours at 60°C (140°F)	4	Industrial all-purpose tooling system		○			○
HX50*3	Epoxy	190°C (374°F)	40°C (104°F)	8.5 hours at 50°C (122°F)	60 hours	Excellent surface finish		○	○	○	
HXR56*3 **NEW**	Epoxy	185°C (365°F)	40°C (104°F)	8.5 hours at 50°C (122°F)	60 hours	Two layer product for rapid lamination		○	○	○	
TC40*4	BMI	213°C (415°F)	182°C (360°F)	6 hours at 177°C (350°F)	14	High service temperature	○				

*1 after post cure *2 followed by post cure | Sourced from: *3 Europe *4 North America

INTRODUCTION TO COMPOSITE TOOLING

RECOGNISED LEADER IN COMPOSITE TOOLING PREPREGS

With the increasing use of composites in aerospace, the need for superior composite tooling materials is growing. Part fabricators are looking for tools with longer life and tighter tolerances. The market is searching for a trusted technology partner that can provide world class innovation, manufacturing and service.

TenCate Advanced Composites has over 20 years of pedigree in composite tooling. TenCate's AmberTool® composite tooling prepregs represents a comprehensive range that has been sold and utilized successfully throughout Europe.

Low temperature cure profiles combined with the high temperature thermal performance after free standing post cure provides long term tool durability. Under TenCate, these products, along with our long term experience and value have been brought to the North American market. Our comprehensive range of tooling products allows our customers to have complete tool design freedom and flexibility.

TenCate's AmberTool® tooling prepregs allow for high precision for all moulded and machined tooling applications, with a high degree of accuracy. Globally we offer customers complete technical support including bespoke training courses. In Europe, TenCate facilitates a single supplier approach to all composite tooling requirements, from master pattern to material.

STEP-BY-STEP PROCESSING INFORMATION

1.THE MASTER PATTERN

(a) Selection of materials

The selection of suitable materials for the master is of prime importance when striving for dimensional accuracy and optimum surface finish. In order to maximise the benefit of low coefficient of thermal expansion and excellent surface finishes, the following alternative combinations of materials are recommended:

(i) A high quality epoxy tooling block coated with epoxy or vinyl ester surface coat (see Appendix V for suggested ancillary materials) or;
(ii) Epoxy / wet lay-up splashes. There are a number of alternative materials currently in use with TenCate AmberTool®, however, any non-specified materials must be proven by physical testing prior to use.

(b) Vacuum integrity

In all cases, the master must be proved prior to lamination of the mould tool, by carrying out a "mock cure". This will enable any potential problems such as lack of vacuum integrity or poor stability under pressure to be checked before any actual laminate construction (see section 6 - Autoclave cure).

(c) Release coating

Thoroughly degrease the surface using an organic solvent such as Chemlease® Mould Cleaner EZ * allowing all traces to evaporate by drying at 60°C (140°F) for 30 minutes.
* Alternate mould release cleaners may be used, please follow manufacturer's recommendations.

Apply 1 - 2 coats of Chemlease® MPP 712 EZ using a wipe on, buff off technique allowing 30 minutes between coats. After the final coat, allow a minimum of 1 hour to cure at room temperature.

Apply the appropriate mould release as per the manufacturer's guidelines[1]
Heat tool to 60°C (140°F) for one hour to allow all release solvents to be driven off.

1 Europe: Chemlease®2185; North America: Frekote® 44-NC or 770-NC

2. PREPARATION OF MATERIALS

Due to the low temperature curing nature of the prepregs, it is essential for out life to be optimised by keeping it in a frozen state at -18°C (0°F) prior to use. At this stage, the customer may find it appropriate to construct a series of templates to enable single ply kits of materials to be prepared prior to lamination. The following points should be noted:

(a) The material must be allowed to reach room temperature before opening the sealed packaging. This is to avoid formation of condensation on the material surface as it warms up.

(b) Materials should be cut on a clean stable surface that is not likely to introduce any potential contaminants in final layup. Typical surfaces are glass sheet, polypropylene, nylon or rubber.

(c) Individual kits of a single ply each should be prepared and stored in a freezer separately. This will enable operators to ensure a minimal amount of material is out of the freezer at any time - refer to Appendices I and III for ply type and orientation.

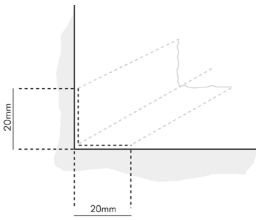
(d) Material can also be pre-cut into a series of conveniently cut squares, typically dimensions of 0.5 m^2, 0.33 m^2 and 0.25m^2 (10, 6 or 2 sq. ft.)

3. LAMINATION TO TOOL

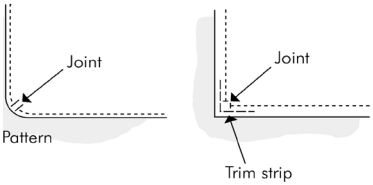
Appendices I and III provide examples of work sheets with easy reference for ply type and fibre orientation. Appendix II shows other common laminate constructions.
The first and final plies will be lighter surfacing plies (lower fibre areal weights) with the composite core made from the heavier material to bulk up the centre of the laminate.

Remove the first appropriate kit of materials from freezer, and allow to thaw. This is essential to avoid formation of condensation on surface.

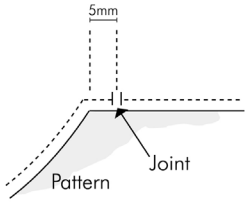
(a) Trim strips – Lay up a series of 45° trim strips into all external corners and tight radii, ensure the pattern runs in a consistent direction for aesthetics. Strips should be approximately 40mm (1 ¼ inch) wide positioned evenly on centre of corner.
Lay-up the first ply, carefully cutting and fitting, bearing in mind the following points:



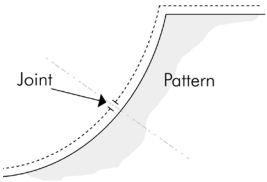
(b) All pieces should be butt joined, no overlaps are permissible at this stage;
(c) The weave pattern should be consistent if the fibre orientation is correct;
(d) Cut material to fit into all external radii and corners taking care not to disturb the trim strips.



(e) On all internal right-angled corners allow material to form around angle, but by no more than 5mm (¼ inch)



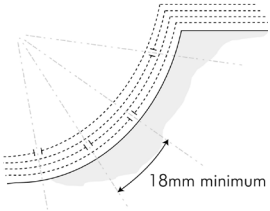
(f) On large external radii the material should be tailored to fit in mid-point of the radius.



(g) Avoid pushing material into corners with a sharp implement, as this is likely to cause unseen damage to fibres and can lead to a structurally weakened laminate.

This procedure is repeated throughout the laminate, with the following additional points for the heavier plies (refer to Appendix I):

HEAVIER PLIES:



(a) All joints should be staggered between plies with a minimum of 18mm (¾ inch) spacing for adjacent plies. Overlaps should be avoided if possible;

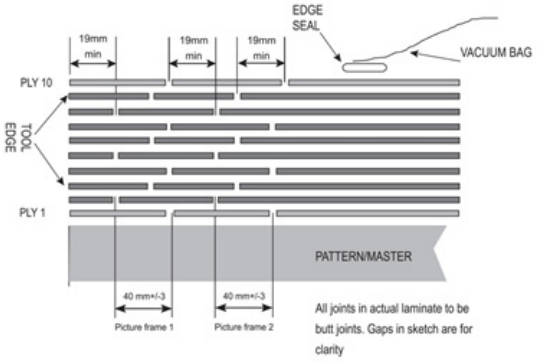
(b) Under no circumstances should any gaps be left as this is likely to cause voids in the completed tool;

(c) The weave pattern should be consistent if the fibre direction is correct;

(d) Avoid pushing material into corners with a sharp implement.

INTEGRITY SEAL

Some tools will be subjected to a large number of autoclave cycles in service, and there is a possibility that the tool surface may become damaged due to operators cutting on its surface or from impact damage. A leak path could possibly form through the damage site and along a fibre bundle exiting at the trimmed edge of the tool. To avoid this, the tool laminate should be laid up in squares. As an additional barrier to this form of leakage, it is desirable to ensure that all fibre bundles are cut at least twice in the area between the strip where the vacuum bag sealant tape will be applied and the tool edge. This will build up a "picture frame" of cut plies around the vacuum bag seal area.

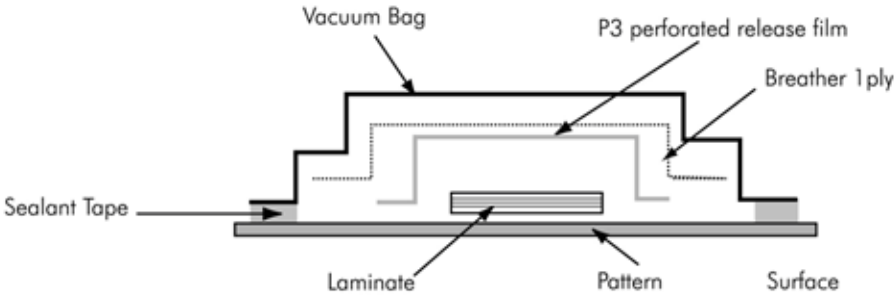


4. DEBULKING (REFERENCE TO APPENDICES I & III)

It is essential to debulk the prepreg at least at the stages stated i.e.:

- After ply 1;
- Approximately every subsequent 3 plies;
- After the final ply has been completed.

This will ensure even consolidation and remove air from the laminate prior to final curing. More complex shapes can sometimes be easier to laminate if more frequent debulks are used, but in these cases the time factor must be taken into consideration.
If a laminate will take more than one day to lay-up, then it must be de-bulked overnight to ensure that it stays in place.



(a) Cover entire laminate surface with a perforated release film type P3, extending beyond the lay-up by approximately 25mm (1 inch).

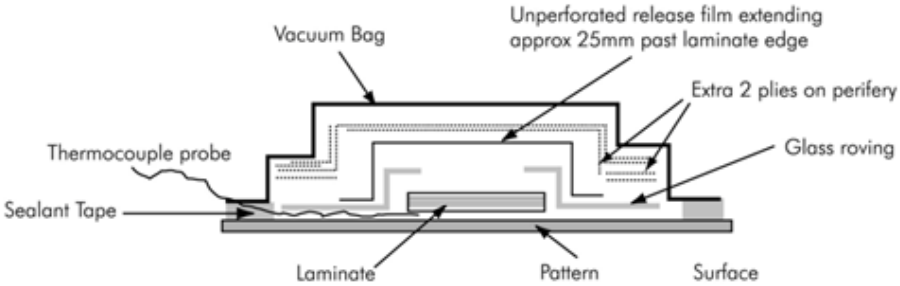
(b) Apply a breather coat of around 350gsm (10.3 oz./yd^2) in total to the surface. Tailor to fit to avoid bridging. At this stage the breather can be omitted from the tightest corners if not practical.

(c) Cover the laminate / assembly with a vacuum bag ensuring that enough slack has been provided to pull into all corners without any bridging.

(d) Apply full vacuum and leave for 20 minutes.

(e) When removing materials from the surface afterwards, be careful not to lift up the previously laminated plies.

5. PREPARATION FOR AUTOCLAVE



(a) Fit a thermocouple underneath the first ply of material on an area that is not a critical mould surface.

(b) Lay in strips of glass rovings every 600mm (24 inch) around the edge of the laminate continuing to the area on the periphery about to be covered with breather and described in (d).

(c) Cover entire laminate with a **non-perforated** release film, extending the edges by around 25mm (1 inch).

(d) Apply a breather coat of around 700gsm total weight, typically 2 plies of 350gsm (10.3 oz./yd^2). Tailor to fit and ensure all areas are interlinked. Fit an extra 2 plies around the periphery between the edge of the laminate and the inside of the vacuum seal. At this stage it is not advisable to miss breather from any of the surface.

(e) Cover with a vacuum bag, ensuring that enough slack has been provided to pull into all corners without bridging. At this stage the vacuum pack will appear very bulky, care must be taken to ensure all materials remain in position as the vacuum bag pulls down.

(f) Apply full vacuum pressure and leave for 25 minutes prior to autoclave processing. Check for vacuum integrity and position of tucks in the bag.

6. AUTOCLAVE CURE

Due to the highly reactive nature of the resin systems, it is essential that curing is carried out under the strictest control possible, to avoid deviation and hence possible exotherm during cure:

1. Apply vacuum pressure and hold at 38°C (100°F) for 30 minutes;
2. Apply 1.45 bar (21 psi) with vacuum;
3. Vent to atmosphere, then raise pressure to between 4.15 bar (60 psi) and 6.20 bar (90 psi);
4. Increase air temperature at 0.5 to 1°C (1-2°F) per minute ramp to the required curing temperature and cure for the stated minimum time.

INITIAL CURING CYCLES (IN HOURS)

Important: Time and temperatures shown are minimums assuming a low mass master model / tool. Increase time at temperature for high mass or thicker master models.

› Initial cure cycles must be followed by a higher temp post cure for ultimate T_g.

If the master used is thin walled, e.g. epoxy / wet lay-up splash, an alternative cure should be used to include a dwell at low temperature. To satisfy this requirement, introduce a dwell at 40°C (104°F) for 2 hours, then continue with the standard cure cycle.

TENCATE AMBERTOOL® PREPREGS

Temperature	HX40	HX42	HX44	HX50	HXR56	TC40
35°C (95°F)						
40°C (104°F)				18	18	
45°C (113°F)				12½	12½	
50°C (122°F)	**40**	**18**	**22**	**8½**	**8½**	
55°C (131°F)	24	11	15	6	6	
60°C (140°F)	18	8	10			
65°C (149°F)	12	5	7			
70°C (158°F)	9		5			
75°C (167°F)	6	2½				
80°C (176°F)				Exotherm risk increases		
182°C (360°F)						See page 12

TENCATE AMBERTOOL® TC40 BMI INITIAL CURE & REQUIRED POST CURE

1. Hold laminate under minimum 28" Hg vacuum at room temperature for a minimum of 24 hours prior to cure. Maintain connection to vacuum during transfer to the autoclave.
2. Maintain initial 28" Hg minimum pressure to bag and increase pressure to 95 +/- 5 psi at maximum 1.5 psi / minute while ramping tool to 129°C (265°F) ±10°F at max 1°C (2°F) / minute.
3. Hold at 129°C (265°F) ±5°C (10°F) for 65 ± 5 minutes based upon lagging thermocouple except proceed to next step if lead thermocouple has been at 129°C (265°F) ± 5°C (10°F) for over 90 minutes.
4. Ramp part temperature to 182°C (360°F) ±5°C (10°F) at a maximum 2°C (4°F) per minute. Hold part at 182°C (360°F) ±5°C (10°F) for 120 to 360 minutes based upon the lagging thermocouple.

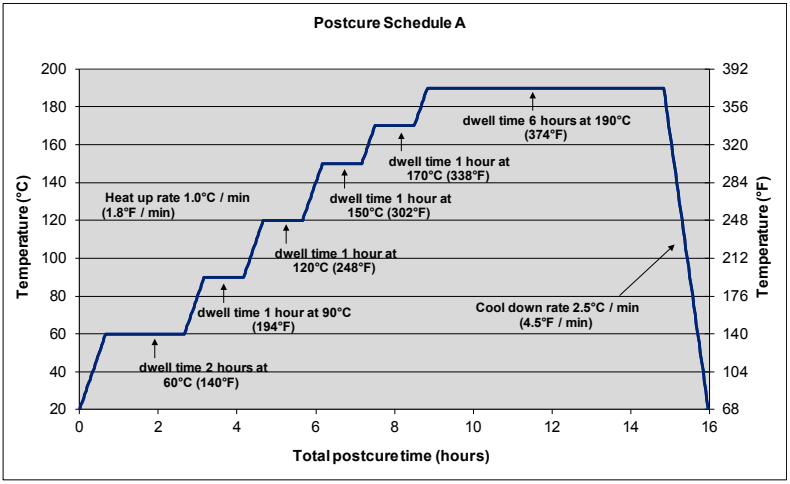
7. REMOVAL FROM MASTER

Should the tool require a backing structure (i.e. to prevent a large tool from distorting under its own weight), it should be fitted at this stage prior to release from the master.
Care should be taken not to induce stresses on removing the tool from the master, since it will be mechanically weak at this stage. The mould should be gently eased off the master and lifted evenly all around.

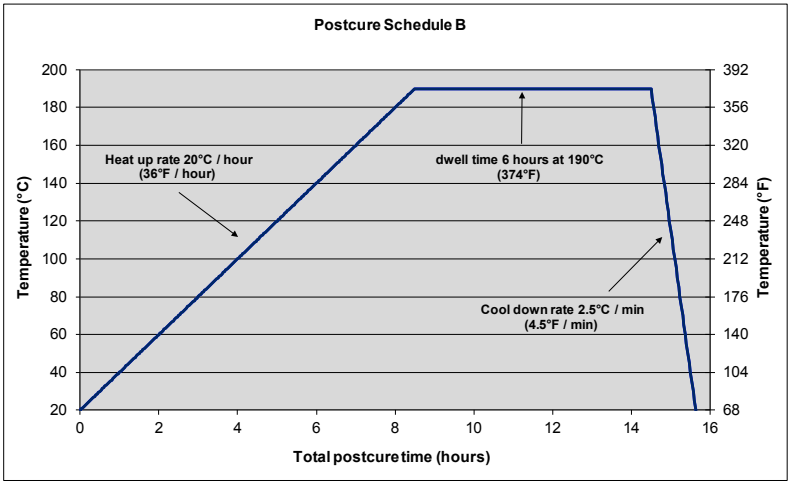
8. POST CURE

The tool should be set up with suitable support around the base with its weight spread as evenly as possible. Carry out any one the following curing schedules from the product data sheet E.g. 120°C (248°F) end use = 140°C (284°F) maximum post cure temperature plus dwell for 6 hours.

Post-cure schedule A (for TenCate AmberTool® HX and HXR series products):		
Ramp	1°C / min to 60°C (140°F)	Dwell for 2 hours
Ramp	1°C / min to 90°C (194°F)	Dwell for 1 hour
Ramp	1°C / min to 120°C (248°F)	Dwell for 1 hour
Ramp	1°C / min to 150°C (302°F)	Dwell for 1 hour
Ramp	1°C / min to 170°C (338°F)	Dwell for 1 hour
Ramp	1°C / min to 190°C (374°F)	Dwell for 6 hours
Cool to 50°C (122°F) at 2.5°C (4.5°F) / min		



An alternative post-cure schedule may also be used as follows for all TenCate AmberTool® products. This is the post-cure schedule recommended for the TC40:



It is essential to carry out post-curing as close as possible to the above schedules to retain maximum end use properties. In cases where the end use temperature is likely to be lower than 180°C (356°F), the post cure can be modified providing the final stage is at least 20°C (68°F) higher than maximum end use temperature, and held at this temperature for the appropriate final dwell time (6 hours). E.g. 150°C (302°F) end use = 170°C (338°F) maximum post cure temperature plus dwell for 6 hours.

9. RELEASE PREPARATION / PRIMING

It is essential to consider the correct regime for coating and releasing the mould at this stage:

(a) Wash surface thoroughly with clean water and allow to dry.

(b) Clean surface with mould cleaner[2], apply with a clean 100% cotton cloth. While the mould surface is still wet, vigorously wipe the mould dry with a second clean cloth, until mould is "squeaky clean" by thumb rub test. Frequently exchange saturated cloths for new ones and repeat several times until all residue is removed. Alternatively, test on an "off part" area with a non-silicone adhesive tape.

Mould preparation and primer (follow manufacturer's guidelines for usage)

(c) For a high quality finish, apply 1 or 2 coats of mould sealer EZ[3] by wipe on / wipe off, allowing 30 minutes between each coat and at least 1 hour at an ambient temperature to finally cure. Use of this product without a release agent may result in severe damage to the mould.

(d) Apply 1 to 2 coats of mould sealer[4] following manufacturer's instructions. Saturate a clean cloth and wipe on a smooth film of no more than 0.6m² (6.5 sf) at a time. When the film begins to evaporate at the edges, wipe the surface with a second clean cloth using a circular motion. Repeat until entire mould surface has been covered. Allow 1 hour at an ambient temperature to cure prior to applying mould release.

(e) Apply 6 wipe on / polish off coats of a release agent allowing 15 minutes between coats and 30 minutes for a full cure at ambient temperature. Follow manufacturer's instructions.

(f) For touch up coats of your selected release agent, apply 2 coats as before.

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2 Europe: Chemlease® Mould Cleaner EZ; North America: Frekote PMC Mold Cleaner, or equivalent

3 Europe: Chemlease® MPP 712 EZ Sealer; North America: Frekote CS-123 mold release sealer

4 Europe: Chemlease® 15 Sealer; North America: Frekote B15 sealer

10. IN SERVICE MAINTENANCE

Points in general to note are:

(a) Avoid any aggressive abrasion on the surface, i.e. when removing components from mould.
(b) Avoid cutting into mould surface during lamination.
(c) Do not use excessive force when releasing from mould.
(d) Follow release agent data sheets as recommended.
(e) Different release agents and different prepregs can have a wide variation in effects on the surface of the mould.

11. RE-PRIMING MOULD SURFACE

Surface deposits can be removed by fine abrasion by hand with either fine nylon scouring pads or cutting paste. Generally, the use of mechanical means is not recommended.

For touch up coats, it is best to do preventative maintenance, therefore reapply after 15 releases, or as trials determine. Wipe on and polish off 1 coat and allow a minimum of 15 minutes prior to recommencing lay-up.

(a) The surface should be cleaned with mould cleaner[2], change cloths frequently and use liberal quantities of cleaner.
(b) Take mould to 60°C (140°F) for 30 minutes to ensure all moisture / solvent is removed.
(c) Revert back to 9 (d) for all release preparation / priming.

FURTHER INFORMATION

For additional information, contact TenCate Advanced Composites at the following locations:

TenCate Advanced Composites
Amber Drive, Langley Mill
Nottingham,
NG16 4BE, United Kingdom
T : +44 (0) 1773 530899
E : tcacsales@tencate.com

TenCate Advanced Composites
18410 Butterfield Blvd.
Morgan Hill, California 95037, USA
T : +1 (408) 776-0700
E : info@tcac-usa.com

www.tencateadvancedcomposites.com
www.tencate.com/tooling

APPENDICES

APPENDIX I. JOB SHEET FOR STANDARD LAY-UP

Below is an example of typical customer job sheet for a carbon fibre reinforced laminate of standard construction with a thickness 5.91 mm (0.23 inches).

Part number:
Job number:
Issue date:

Procedure (gsm)	Ply no.	Fibre orientation	Pattern direction	Operator(s)	Inspected	Date
Trim strips 205 2x2T	-	+/- 45°	-			
Laminate 205 2x2T	1	0°	↗			
Debulk						
Laminate 650 2x2T	2	0°	↗			
Laminate 650 2x2T	3	+ 45°	↑			
Laminate 650 2x2T	4	- 45°	→			
Debulk						
Laminate 650 2x2T	5	90°	↖			
LAMINATE MID PLANE						
Laminate 650 2x2T	6	90°	↖			
Laminate 650 2x2T	7	- 45°	→			
Debulk						
Laminate 650 2x2T	8	+ 45°	↑			
Laminate 650 2x2T	9	0°	↗			
Laminate 205 2x2T	10	0°	↗			
Final debulk						
Preparation for autoclave						
Autoclave cure						
Post cure						
Preparation and release prime						

APPENDIX II. AUTOCLAVE LAMINATE CONSTRUCTIONS

COMMON LAMINATE CONSTRUCTIONS

For autoclave cured tools

1. CARBON FIBRE EPOXY LAMINATES

(a) 1 ply 205gsm 2x2 Twill
8 plies 650gsm 2x2 Twill Approx. thickness = 5.3mm (0.2 inches)
1 ply 205gsm 2x2 Twill
Typical application: Medium sized mouldings requiring high stability and low C.T.E. (Appendix I describes this laminate)

2. GLASS FIBRE LAMINATES

(a) 1 ply 300gsm 8 H Satin (yarn) Approx. thickness = 5mm (0.2 inches)
8 plies 860gsm 8 H Satin (yarn) (Reverse fibre direction from centre
1 ply 300gsm 8 H Satin (yarn) to achieve fully balanced laminate)
Typical application: High stability mouldings where C.T.E. is not a major concern.

(b) 1 ply 300gsm 8 H Satin (yarn) Approx. thickness = 5mm (0.2 inches)
8 plies 870gsm 2x2 Twill (roving) (Reverse fibre direction from centre to achieve fully balanced laminate)
1 ply 300gsm 8 H Satin (yarn)

(c) North America
1 ply 292gsm 8 H Satin (yarn) Approx. thickness = 6mm (0.27 inches)
8 plies 875gsm 2x2 Twill (roving) (Reverse fibre direction from centre to achieve fully balanced laminate)
1 ply 292gsm 8 H Satin (yarn)
Typical application: More economical version of 2(a)

3. CARBON FIBRE BMI LAMINATES

(a) 10 plies 370gsm 6k 2 x 2 Twill Approx. thickness = 4 mm (0.14 inches)

Other laminate specifications may also be utilised.

APPENDIX III. PROCESSING PROCEDURE FOR HXR-SERIES

TYPICAL LAY-UP PROCEDURE

For a carbon fibre reinforced laminate using TenCate AmberTool® HXR-series

Procedure (gsm)	Ply no.	Fibre orientation	Pattern direction
Trim strips 205 2x2T	-	+/- 45°	-
Laminate 205 2x2T	1	0°	↗
Debulk			
HXR56 101	2	0°	↗
HXR56 101	3	0°	↖
	LAMINATE MID PLANE		
HXR56 101	4	0°	↖
HXR56 101	5	0°	↗
Debulk			
Laminate 205 2x2T	6	0°	↗
Preparation for autoclave			
Autoclave cure			

COMPARISON OF HXR* LAY-UP VS. APPENDIX I

TenCate AmberTool® summary	HXR lay-up	standard lay-up
Individual plies	6	10
Debulks	3	4
Total fabric weight	5.41 kg/m^2	5.61 kg/m^2
Laminate thickness	5.5 mm	5.91 mm

*TenCate AmberTool® HXR is an inherently quasi-isotropic prepreg allowing more efficiency by reducing the number of debulks.

APPENDIX IV. MACHINING OF AMBERTOOL PRODUCTS

Utilizing the correct machine tool, speeds and feeds, TenCate AmberTool® HX-series of composite tooling prepregs can be machined, blocked and prepared to produce a near-net moulded surface.

Pocketing*
Surface Feet per Minute (SFM) – 800
RPM – 6.112
Chip Load / Tooth – .004 Feed / Rate - 50" / min.
Axial Depth / Pass – .0625"
Radial Width of Cut – 0.07" (.0025 mm Cusp Height)

3D Contour*
SFM – 800
RPM– 6.112
Chip Load / Tooth – .002 Feed / Rate - 25" / min.**
Axial Depth / Pass – .025"
Radial Width of Cut – 0.07" (.002 mm Cusp Height)

Both conditions use Robb Jack Cutter P/N – PCD-201-16BN (½" Ball, 2 Flute PCD)
For more information, refer to RobbJack.com/campaign/composite-machining
* Based on Mori Seiki NV5000AI 30AP
** Could be increased to 50"/ min. depending on rigidity of part

APPENDIX V. ANCILLARY MATERIALS

Suggested ancillary materials - Europe

Model materials

Rampf WB-0700 with density matched adhesive and repair paste – distributed by TenCate

Axson Lab 975 and adhesive

EC85 Hard Epoxy Surface Coat – available exclusively from TenCate

Cleaners and releases - distributed by TenCate

Chemlease® MPP712EZ Sealer

Chemlease® 2185 Mould Release

Chemlease® Mould Cleaner EZ

Chemlease® 15 Sealer EZ

Chemlease® 255 Release Agent

Chemlease® PMR EZ Release Agent

Vacuum bagging supplies

Bagging film – Tygavac KM1300

P3 and NP ETFE release film – Tygavac WL5200B P3 & NP

Autoclave breather 350gsm – AW N10

Tacky tape/bag sealant – AT200Y

Support structures

Cellite 180°C honeycomb backing board – available from TenCate (Europe only)

180°C gusset boards – available from TenCate (Europe only) or Advanced West (North America only)

Ancillary materials can be supplied:

Europe:

TenCate Advanced Composites

T : +44 (0) 1773 530899

E : tcacsales@tencate.com

North America:

Advanced West (Jim Cook)

T : ++1 (714) 920-8060

E : james.advanced@gmail.com

NOTES

ADVANCED COMPOSITES

Processing information

TENCATE ADVANCED COMPOSITES

Amber Drive, Langley Mill
Nottingham,
NG16 4BE, United Kingdom
T : +44 (0) 1773 530899
E : tcacsales@tencate.com

TENCATE ADVANCED COMPOSITES

18410 Butterfield Blvd.,
Morgan Hill,
California 95037, USA
T : +1 (408) 776-0700
E : info@tcac-usa.com

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