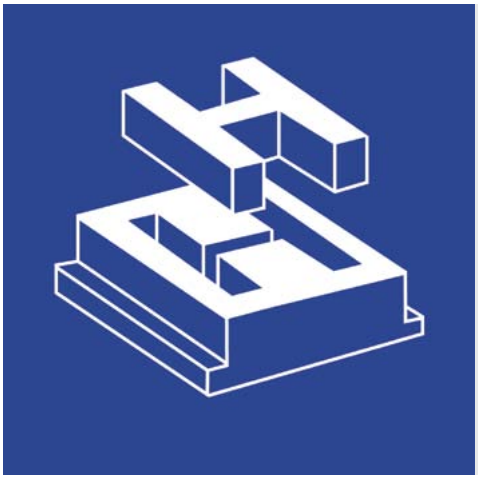


Hexcel Tooling Fabrics User Guide

HEXCEL®

Hexcel tooling fabrics are high-performance carbon fiber fabrics which utilize Hexcel's proprietary PrimeTex™ fabric technology. This unique fabric architecture provides ribbon-like tow structure resulting in a homogenous laminar morphology significantly minimizing any resin-rich pockets normally seen in other tooling fabrics. Our PrimeTex™ fabric technology reduces interstitial spaces resulting in an enhanced tool surface aspect with smoother part reproduction and less post cure re-work of part surfaces. Hexcel tooling fabrics are available with M61, a high glass transition temperature (T_g) bismaleimide resin system based on Hexcel's high performance aerospace matrix technology specifically modified for rate-durable carbon tools.

Benefits

- PrimeTex™ fabrics have reduced resin-rich pockets resulting in higher durability and enhanced part quality
- High T_g resulting in high-rate tools for 350°F cure.
- Available in either standard modulus or intermediate modulus 3, 6 and 12K fibers
- High fiber volume fraction
- Excellent tack and drape
- Excellent out-time

Regular weaving style (left) and PrimeTex™ (right) fabrics.

Uncured Prepreg Properties

Property	Value	Comment
Nominal Resin Content	38%	By Weight
Standard Fabric Areal Weights and Construction (Other AFW and styles available upon request)	196 g/m²; 3K; Plain Weave 380 g/m²; 6K; 8 Harness Satin 670 g/m²; 12K; 5 Harness Satin	Available in AS4 and IM2 Fibers
Tack Life	20 days	Medium Tack
Minimum Viscosity	22.4 Poise	RDA
Out Life at 70°F (21°C)	30 days	
Storage Life	6 months after shipment	0°F

Cured Laminate Properties

Property	Value	Comment
Cured Ply Thickness 196 g/m^2 380 g/m^2 670 g/m^2	0.0078 in (0.198 mm) 0.0150 in (0.381 mm) 0.0240 in (0.609 mm)	Based on nominal areal fiber weight.
T_g (Dry)	527°F (275°C)	DMTA, Post-Cured
Maximum Use Temperature	425°F (218°C)	Post-Cured
Coefficient of Linear Thermal Expansion	1.67 x 10^{-8}/°C	TMA
Minimum Initial Cure Temperature	375°F (191°C)	Post-Cure Required at 425°F (218°C)

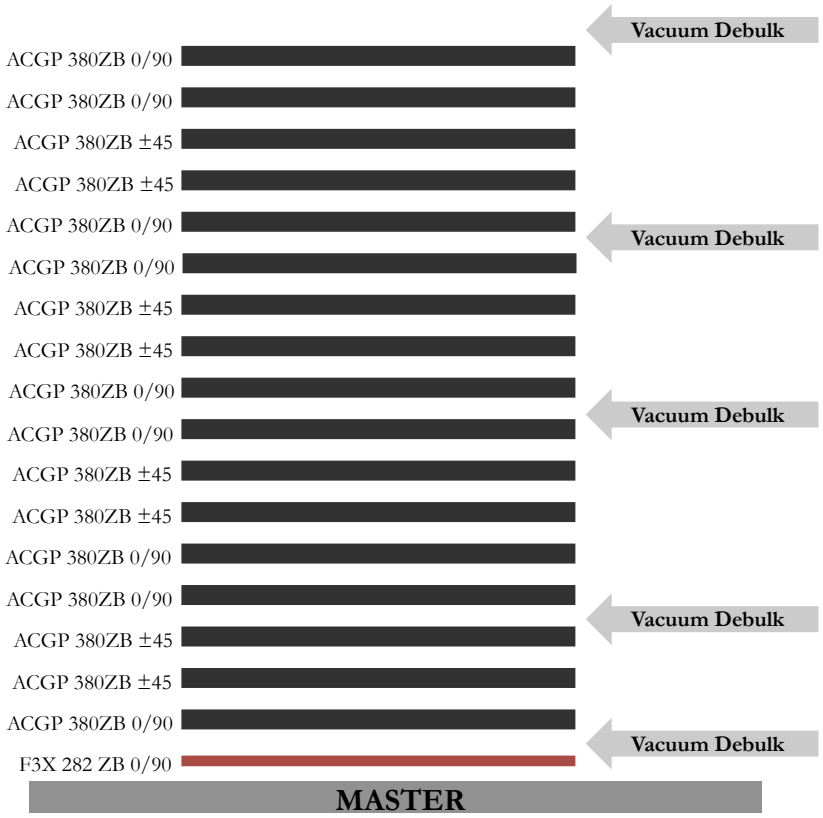
Cured Mechanical Properties

Laminate Property Units	Temperature°F (°C) & Condition	Value
Flexural Strength ksi (MPa)	75 (24) Dry 450 (232) Dry	151 (1041) 103 (711)
Flexural Modulus msi (GPa)	75 (24) Dry 450 (232) Dry	8.33 (57) 7.88 (54)
Short Beam Shear Strength ksi (MPa)	75 (24) Dry 450 (232) Dry 350 (177) Wet	9.95 (69) 7.35 (50.7) 5.02 (34.6)
CAI (270 in-lbs/in impact) ksi (MPa)	75 (24) Dry	30.4 (209)
Tensile Strength ksi (MPa)	75 (24) Dry	122 (841)
Tensile Modulus msi (GPa)	75 (24) Dry	8.1 (55.9)
Compression Strength ksi (MPa)	75 (24) Dry 450 (232) Dry 350 (177) Wet	114 (786) 77 (531) 59.4 (409.5)

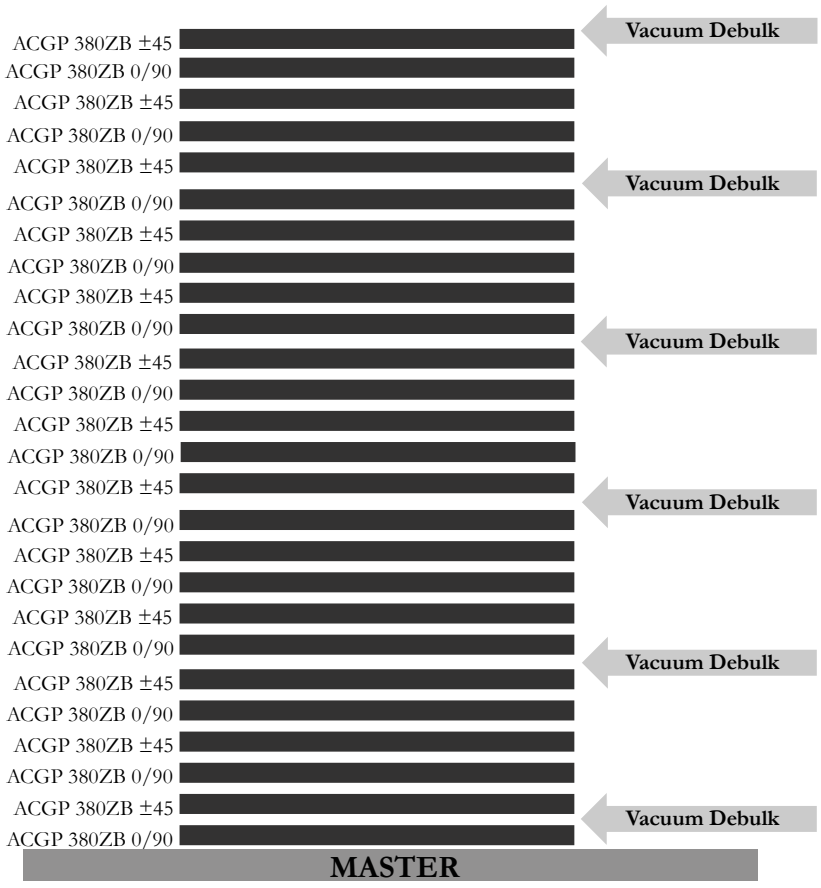
Lay-Up

Two basic lay-up schedules are shown for 0.25 inch (6.25 mm) and 0.4 inch (10.2 mm) net thickness face sheets. Oven vacuum debulks are recommended as described below for nominal tool geometries. Ply lay-up and debulking schedules should be optimized for unique or complex tool geometries.

Lay-Up Schedule for 0.25 in Face Sheet



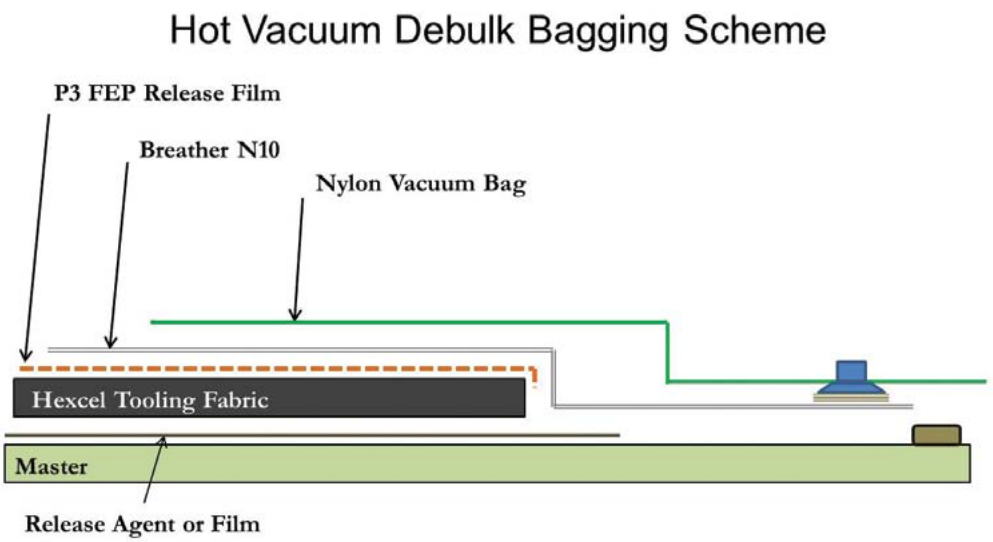
Lay-Up Schedule for 0.40 in Face Sheet



Hot Oven Debulk Bagging Scheme and Oven Cycle

Bagging for Hot Oven Vacuum Debulk

1. Perforated FEP release film should be placed on top of the tooling fabric.
2. A layer of N10 breather cloth should be placed on top of the perforated FEP film.
3. A nylon BMI-resistant vacuum bag is placed on top of the N10 breather and sealed to the master or project plate using temperature-appropriate sealant tape.



Oven Cycle

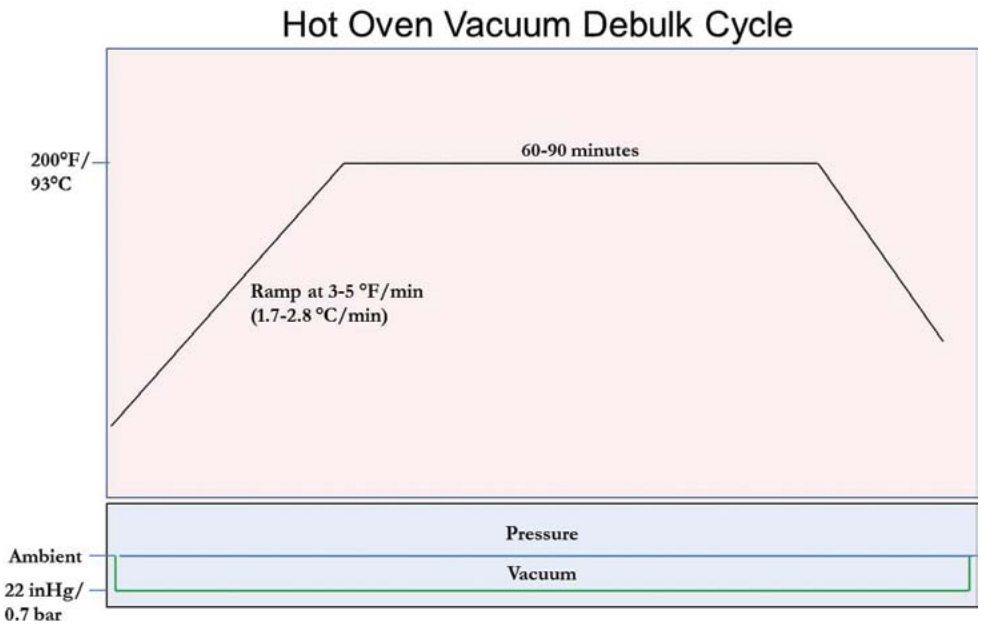
Minimum vacuum requirement of 22 inHg (0.7 bar) when measured mid-span with vacuum applied at the ends.

Oven Temperature Profile

- Heat to 200˚F (93˚C) at 3-5 ˚F/minute (1.7-2.8 ˚C/minute).
- Start one hour dwell when lagging TC reaches 190˚F (88˚C) for a maximum dwell of 60-90 minutes.
- Cool down at 5 ˚F/minute (2.8 ˚C/minute) to 120˚F (49˚C).
- Opening of oven doors to accelerate cool down is allowed.
- Disconnect vacuum and end cure when lagging TC is below 120˚F (49˚C).

Recommended Inspection Requirements:

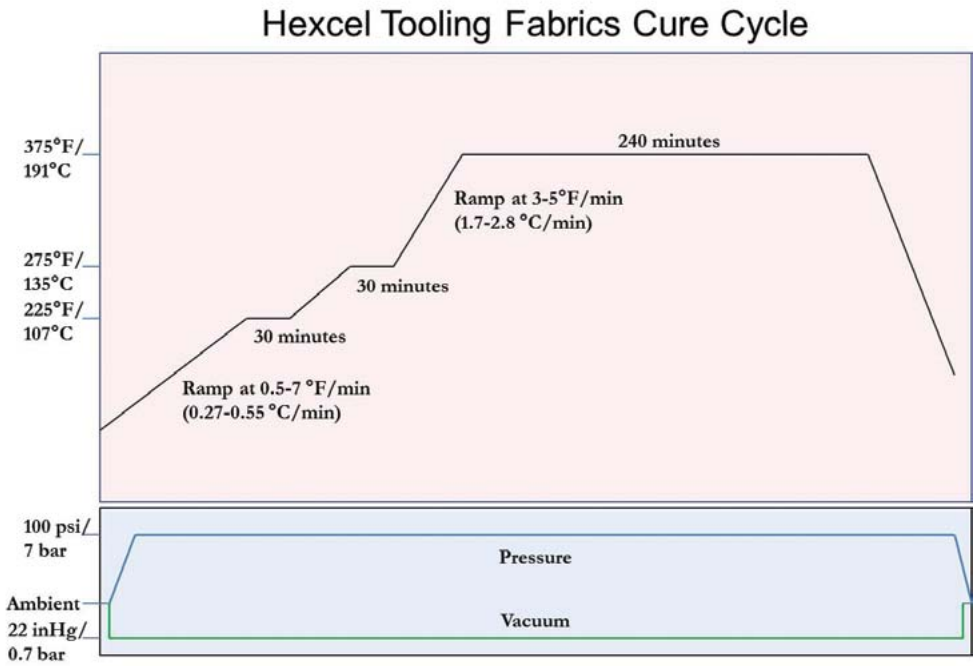
- Verify lagging TC achieves minimum time at dwell temperature and doesn't exceed maximum dwell temperature.
- Verify air TC doesn't exceed 210˚F (99˚C).



Cure Cycle

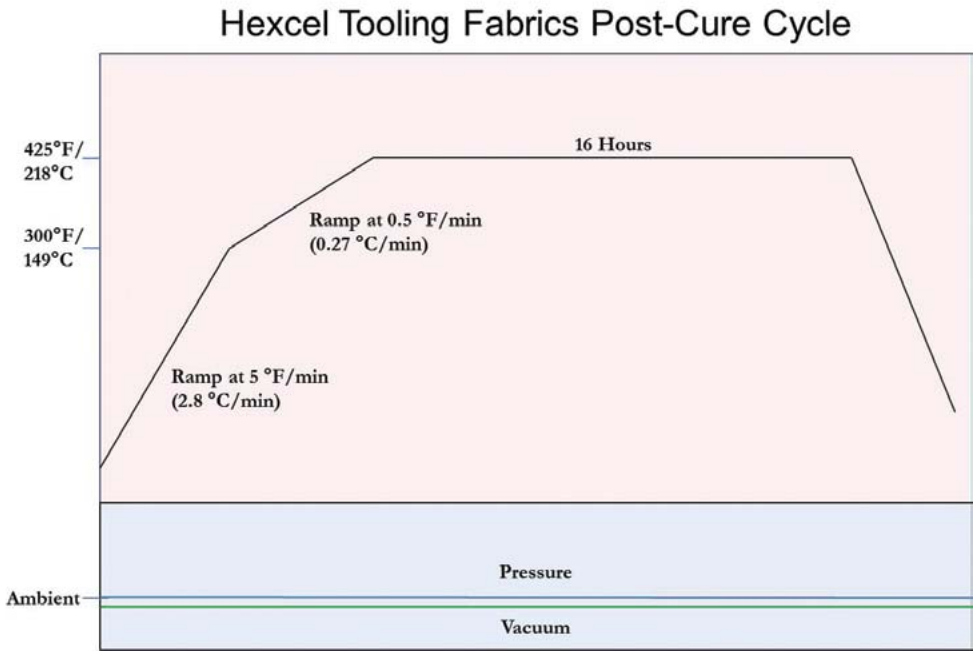
Establish a minimum vacuum of 22 inHg (0.7 bar).
Maximum allowed vacuum bag leak is 2 inHg (0.067 bar) in 10 minutes.

- Begin heating at 0.5-1 °F/minute (0.27-0.55 °C/minute) to 225°F (107°C).
- Increase pressure to 100±10 psi (6.89±0.69 bar).
- Dwell at 225±5°F (107±2.8°C) based on lagging thermocouple for 30+10/-0 minutes.
- Continue to heat 0.5-1 °F/minute (0.27-0.55 °C/minute) to 275°F (135°C).
- Dwell at 275±5°F (135±2.8°C) based on lagging thermocouple for 30+10 /-0 minutes.
- Continue to heat at 3-5 °F/minute (1.7-2.8 °C/minute) to 375°F (191°C).
- Dwell at 375±5°F (191±2.8°C) based on lagging thermocouple for 240 +30 /-0 minutes.
- Cool at a maximum of 5 °F/minute (2.3 °C/minute) to 120°F (49°C) before releasing pressure.



Post-Cure Cycle

- Begin heating the tool at a maximum of 5 °F/minute (2.8 °C/minute) to 300°F (149°C).
- When leading thermocouple reaches 300°F±5°F (149°C±2.8°C) reduce ramp rate to a maximum of 0.5 °F/minute (0.27 °C/minute) and continue heating to 218°C (425°F).
- Cool at a maximum rate of 5 °F/minute (2.8 °C/minute) to 150°F (65°C) before removing from the oven.
- Allowed to open door at 240°F (116°C) based on a lagging TC to assist with cool down.



Thermocouple Placement

- For small tools less than 8 ft^2 (0.74 m^2) in surface area a minimum of four thermocouples (TC) will be used. An additional two TC's will be used for each additional 10 ft^2 (0.93 m^2) of surface area.
- Thermocouples shall be placed to measure leading and lagging tool temperatures. Placement of thermocouples shall be such that the tool's thermal gradient is accurately captured during the cure.
- Leading tool temperature is typically the outer or bag surface directly in the air flow path of the autoclave.
- In cases with a foam tool master, the lagging tool temperature is typically located between the inside plies and the master. In the case of curing against a metal or composite master, lagging temperature will typically be at the mid-ply or half the total thickness of the thickest area of the tool.
- For both leading and lagging TC placement, the probe end shall be placed a minimum of three inches from the edge of the tool.
- Distribution of leading and lagging TC's shall be such that reasonable areas of the tool surfaces are surveyed.
- Actual placement will depend on factors such as tool geometry, tool thickness variation and curing systems air flow. Please contact Hexcel Technical Support if additional help is required for your particular tool.

Bagging

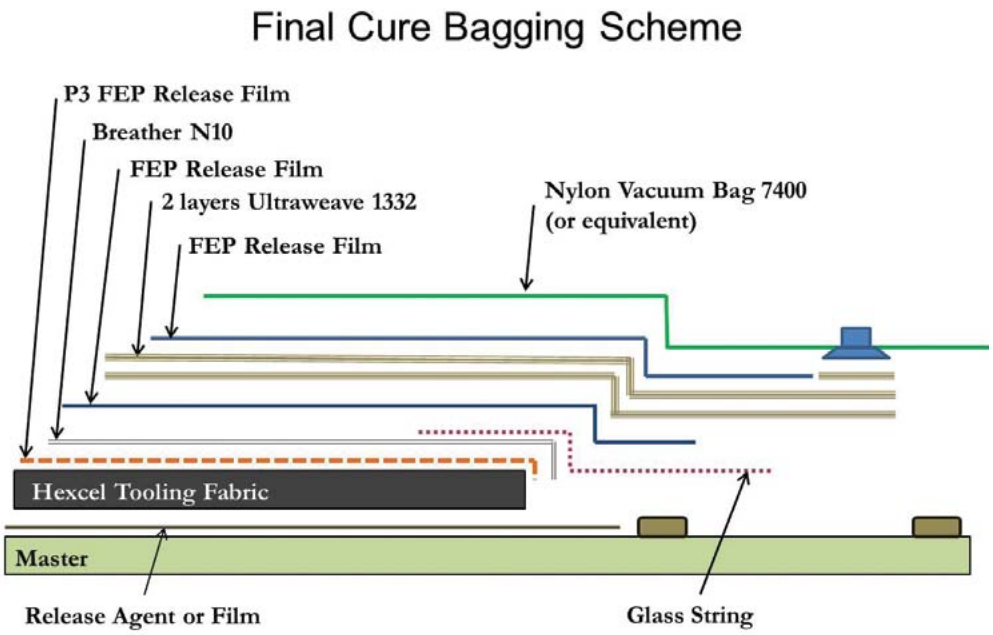
- The following bagging materials are required. Recommended products and generic requirements for alternatives are in the table below.
    - o Sealant tape to withstand autoclave temperatures of 400°F (200°C)
    - o Perforated and non-perforated release films
    - o Breather/bleeder materials
    - o BMI resistant vacuum bag

- A typical bagging assembly is outlined in the figure below.
- If you are using materials not listed in the table below please contact your Technical Support representative.

Material	Recommended Material	Generic Requirements
Nylon Vacuum Bag	WL7400 DP 1000 WL8400 HS8171 HS9171	BMI resistant
		350-400°F (177-204°C) service
		Suitable for long duration temperature and pressure
Solid Release Film	Wrightlon 5200 HT-7000	BMI resistant, 0.05 mm (0.002 in) thick
		400°F (204°C) service
Breather (outer bag)	Ultraweave 1332 RC-3000-20	400°F (204°C)/ 7 bar (100 psi) service
		Suitable for long duration temperature and pressure
Breather / Bleeder (inner bag)	N 10 RC-3000-10	339 g/m^2 (10 oz/yd^2) polyester non-woven
Perforated Release	5200 P3 HT-7000 P1	BMI resistant
		400°F (204°C) service
		clean punched holes 0.38 mm diameter (0.015 in) on 6.35-12.7 mm (0.25-0.5 in) centers
Glass Breather String	ECG 37 1/4 dry glass tow	Glass tow of equivalent size

- Contact between the matrix resin and the vacuum bag must be prevented.
    - o To achieve this the non-perforated release film used in the bagging scheme, must be sealed to the tool during bagging. In effect, this will create an isolated interior bag. The BMI resin will have no adverse effect on this non-reactive and stable release material.
    - o Glass strings (or strips of PTFE/Teflon coated glass) are used to connect the interior bag to the exterior vacuum source. These should be positioned around the perimeter of the tool at approximately 12 inches (30 cm) spacing and they should pass over the interior bag vacuum tape.
    - o As an extra precaution, an additional layer of non-perforated release film can be placed over the breather fabric.

These steps are expanded upon below in the Step-by-step Bagging Instructions.



Do not skip steps in these instructions. Each step is critical to successful cure of the Hexcel Tooling Fabric part.

1. Apply a layer of sealant tape around the perimeter of the material. This sealant tape will serve as an attachment and sealing point for the inner bag.
2. Apply a layer of perforated FEP film directly over the material. It is recommended that Teflon tape is used to attach the perforated FEP to the tool master to prevent it from shifting during subsequent bagging steps or cure.
3. Apply a single layer of breather material over the perforated FEP.
4. Apply fiberglass breather strings approximately every 12 inches (30 cm) around the perimeter of the tool. The strings provide a pathway to connect the inner bag to the outer vacuum supply to remove air from the laminate and get optimum consolidation of the material while protecting the outer bag from aggressive BMI resin.

   To apply these strings:
   - Cut a length of fiberglass tow approximately 24 inches (60 cm) long.
   - Fold the string in half. Tape the loop at the top to the breather, allowing approximately 6-8 inches (15 cm to 22.5 cm) of string to hang over the edge of the sealant tape.
   - Rip the sealant tape paper covering where the string runs over the tape and press the tow down into the tape.
   - Place the paper covering back over the tape to prevent debris from sticking to the tape before the inner bag is applied.

   If there is not enough room on the tool master to leave the breather strings hanging the ends can be taped on top of the inner bag once it has been applied to the tool.

5. After all layers of breather/bleeder and strings have been applied to the tool the inner bag made of solid FEP film can be installed. It should be sealed to the master using the layer of sealant tape that had previously been applied.
    - When seaming two smaller pieces of FEP or bag film together to make a larger piece, the vacuum tape should be positioned between the faces like pages between book covers to allow for complete sealing of the seam to the perimeter vacuum tape.
6. Two layers of Ultraweave 1332 should next be applied on top of the solid FEP inner bag. Additional strips should be applied to corners and edges to prevent damage to the vacuum bag.
7. Place a second layer of solid FEP on top of the breather to further protect the final nylon vacuum bag from the BMI resin.
8. Vacuum ports should be installed on top of the last layer of Ultraweave.
    - A minimum of 4 ports (3 vacuum, 1 sensor)
    - For larger tools, the suggested quantity of vacuum ports is 1 port per 10-15 ft^2 (0.93-1.39 m^2) of tool area.
    - The vacuum ports should be connected to each other underneath the bag by strips of breather or some other non-collapsing, highly permeable material.
9. Place strip of vacuum sealant tape onto project plate or master (if master is of high vacuum integrity).
10. Install final bag by sealing it to the vacuum sealant tape. Bag should be large enough to prevent bridging.

Storage and Handling

Store the product with the roll core sitting horizontally and support at core ends in its original (or equivalent) sealed packaging at 0°F (-18°C). Prevent condensation on the product by warming to room temperature before opening vapor barrier bag (reseal for subsequent storage). The usual precautions when handling uncured synthetic resins and fine fibrous materials should be observed. See Material Safety Data Sheet. The use of clean disposable impervious gloves provides protection for the operator and avoids contamination of material and components.

Important

Hexcel Corporation believes, in good faith, that the technical data and other information provided herein is materially accurate as of the date this document is prepared. Hexcel reserves the right to modify such information at any time. The performance values in this data sheet are considered representative but do not and should not constitute specification minima. The only obligations of Hexcel, including warranties, if any, will be set forth in a contract signed by Hexcel or in Hexcel's then current standard Terms and Conditions of Sale as set forth on the back of Hexcel's Order Acknowledgement.

For more information

Hexcel is a leading worldwide supplier of composite materials to aerospace and other demanding industries. Our comprehensive product range includes:

- Carbon Fiber
- Reinforced Fabrics
- Carbon, Glass, Aramid and Hybrid Prepregs
- RTM Materials
- Engineered Core
- HexTOOL® Composite Tooling Material
- Structural Film Adhesives
- Honeycomb Cores

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