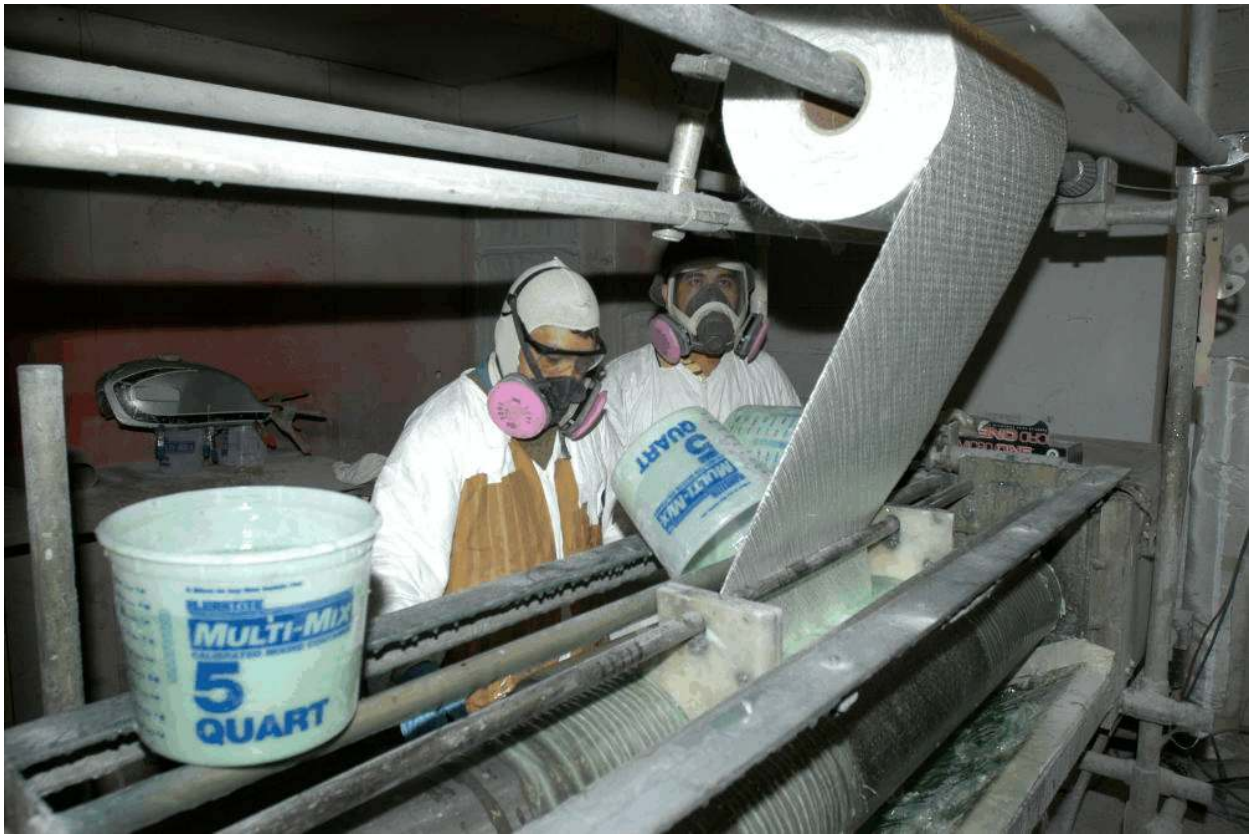


WETPREG BOATBUILDING AT BOSTON BOATWORKS

A visit to a shop that has fully integrated vacuum bagged epoxy wetpreg laminates into production boatbuilding.

Dan Spurr and I visited BBW in April, 2005, and Dan's article will cover their business and products in detail. I am going to share my observations on their advanced composite construction practices, specifically the use of a large fabric impregnator to produce just in time wetpreg laminates that are then vacuum bagged, room temperature cured , and ultimately high temperature postcured.

The impregnating machine at the heart of the BBW production process lives in a dimly lit alcove off the main shop, both out of the way of mold , materials, and part movements, yet close enough for easy transport of wetpreg reinforcements, rewound onto cardboard or PVC tube carriers, into the tooling. I designed and built this fabric impregnator in 1991, and it was nice to see it again, and in operation, albeit with a few more miles of fabric run through it and more resin stuck to it than when it left my shop.

BBW's Scott Smith told me "When Mark Lindsay had the impregnator at his shop in Gloucester , MA, it was used to build eight mid-size sailboats and two powercats. Hull number twenty-seven of the Zurn design is now underway (June 21, 2005) in our Boston shop, so we have built quite a few things with the machine, not to mention lots of smaller parts and some architectural projects too. " I asked Smith a few more questions about the impregnator, and what he would like to change, and we'll look at those topics in just a moment.

One critical issue when switching to wetpreg production instead of in-situ wet layup is that the impregnating device can reliably produce enough material to keep up with the placement crews demands. Once the impregnator is fired up the crew in the mold can basically forget about wetout issues, up to and including details about how the impregnator is running. Fabric wetout is now someone else's job. The placement and tailoring personnel should be able to rest assured that the fabrics they receive have the correct resin content, and in the case of BBW, are also cut very close to their final lengths because the impregnator operator is carefully watching the footage counter. The second critical issue is almost the polar opposite of the first - synchronizing the output of the impregnator so that the placement crew is not overwhelmed with excess wetpreg that can't be applied within the working time window before the process materials and bag have to be in place.

WHY WETPREG ?

I asked Mark Lindsay and Scott Smith why they elected to build a production vacuum bagged epoxy powerboat with 'wetpreg' style reinforcements instead of frozen B staged prepregs, or some sort of infusion process. All these systems require vacuum bagging and oven curing steps, so why go with wet pregs? According to Mark Lindsay, " We were familiar with using the impregnator from previous one-off projects, and were confident we could achieve bigger economies when building multiples of the same boat. We never did that before. This is not a race boat, " he added, " and we are not going for an extremely low resin content in our laminates - the goal is a well consolidated, void free laminate that can be produced in a reasonable amount of time. We want the resin," he told me, " exactly where we want it.

BBW PROJECT PHOTO(S) HERE

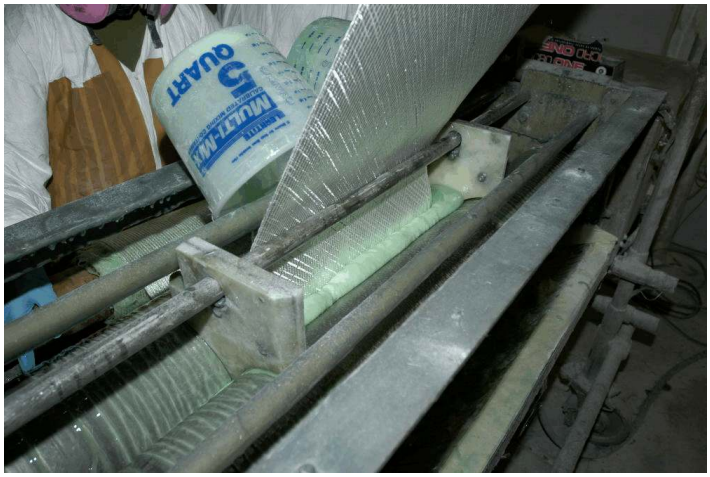
"When I worked at Hercules (an early producer of carbon fiber reinforcements and finished parts,) " Lindsay continued," on the J Hawk projects, some spots in the boat had 90 to 100 layers of prepreg laminate only 0.006" thick, with a debulk cycle after every 2 plies. With our wetpregs," Lindsay continued, " we can run much thicker reinforcements, apply multiple layers in one gel cycle, and assemble hull, deck, and part skins in only one bag cycle because the resin is still liquid, not B staged and 'locked-up' except for a brief period when the resin liquefies during the cure cycle. The bag works on our laminates for quite a while before the resin gels. It's easier to move bubbles around and out of the core kerfs and the wetpreg laminate stack with our

resin's low viscosity."

Smith and Lindsay noted that selecting the correct perforated release film is critical to producing well consolidated laminates that have not bled too much resin and become aerated. "Wet pregs also have advantages when working with cores, " Lindsay added, " especially contour cut cores. We devote a lot of time and effort to epoxy putty filling all the core kerfs on a special curved fixture. The putty is completely compatible with the adjacent laminating resin. With prepreg construction a film adhesive would typically be used to bond core block faces - filling the kerf system remains difficult - even if you use a special kerf or butt splice filler-adhesive that expands when heated. "

THE IMPREGNATOR

The efficiently choreographed laminating procedures at the BBW shop were fascinating to watch. The shop's big, high output impregnator could bury these guys in wetpreg, but didn't. The machine's output rate was closely matched to the human's application rate. Two and sometimes three multi-man placement crews worked inside the Z mold during framing lamination . More people would not fit, and the ones that do have all of the wetout and rewound fabric that they can handle. The application sequencing was both methodical and efficient, setup so they worked without ever having to walk or stand on any of the wetpreg materials.

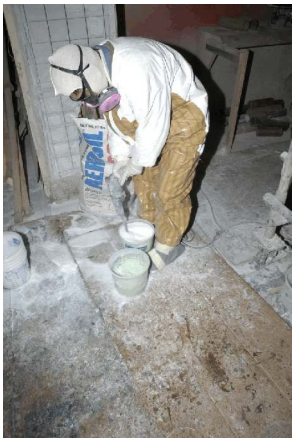


CAPTION: The slightly thickened Pro Set resin showed good resistance to drainout, both in the impregnator bath and in the laminates.

On the day I visited BBW the two and a half man crew (the resin mixer who fed the impregnator's dip bath spent about half his time walking rewound rolls of wetpreg over to the placement crew,) at the impregnator were producing laminate tapes approximately eighteen to thirty inches wide. The reinforcements, from Johnson Industries had been slit to width by BBW's fabric supplier Composites One, (Bristol, RI) . Lindsay agreed with me that the true edges and uniform rewind tensions that typically come from vendor slit material instead of shop-cut, track straighter and run better through the impregnator. I did not see any significant fraying of the cut edges, and no 'windup-snags' on the impregnator rolls or when the materials were unwound in the mold, during an afternoon of observing.

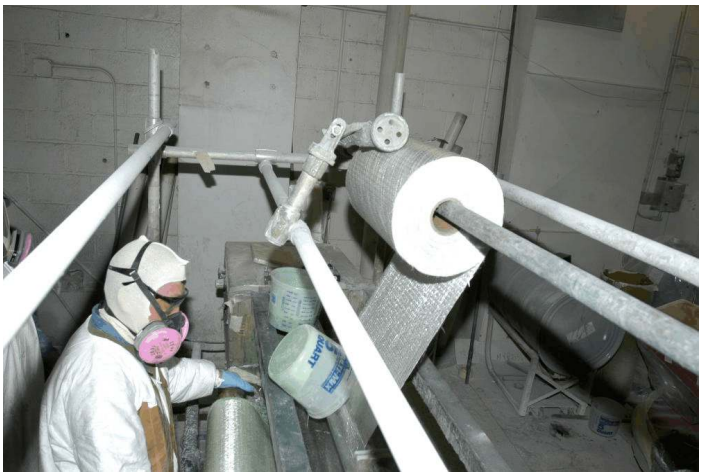
The BBW impregnator is fed by the 'bucket-batch' method, even when running

full-width heavyweight reinforcements. Resin that leaks around the dams containing the nip bath is occasionally scraped off the rotating rolls, and drops down onto the polyethylene film that lines the impregnator's inclined drip tray, which drains into a large waste bucket. Escaped resin is *never returned to the wetout bath*, due to its unknown remaining working time.



CAPTION: The BBW impregnator is bucket-batch fed, with the resin and hardener, first combined with a low-shear powered mixer, and then slightly thickened with fumed silica.

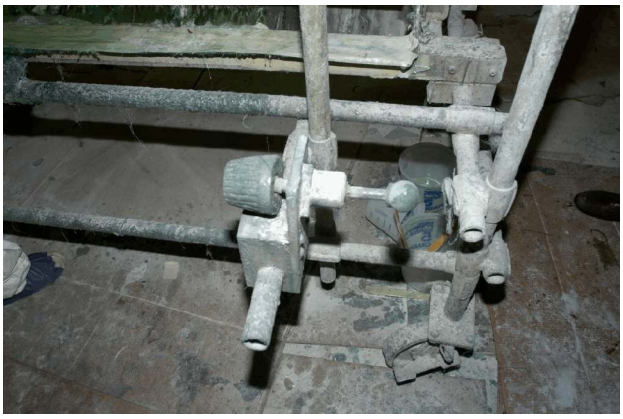
Smith commented that adding meter/mix/dispense equipment to the impregnator was on the shop's wish list." Our guys spend a lot of time mixing resin and hardener, and then adding fumed silica to it. A equipment setup that would provided pre-thickened and premixed resin to the dip bath with the push of a button would really be nice. We looked at high output equipment with gear pumps and static mixers a while ago, but did not buy it. Now that we are running the impregnator so much, I wish we had."



CAPTION: The machine operator, while manually rewinding wetpreg onto the cardboard core, looked up frequently at the footage counter that rests on the unwind roll. Most rewound materials that I saw handed into the mold were precisely cut to length, with no end-trim required by the placement crew members.

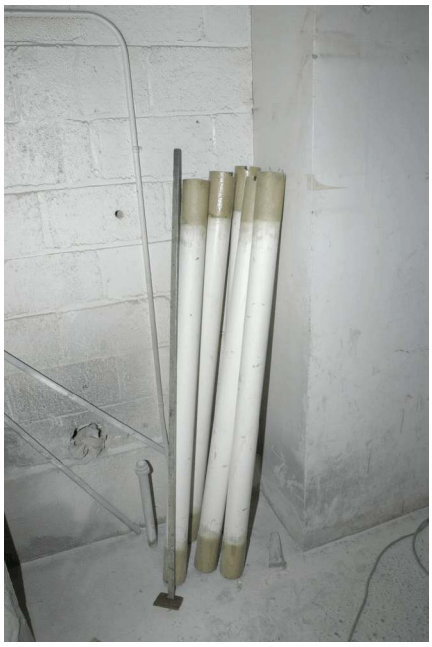
Note two interesting details in this photo - first, the narrow wetout material is being manually rewound onto a cardboard core. Second, the roll of dry fiberglass above the nip is sitting off-center on the unwind arbor, with no side-stops or cone collars to align or center it. This setup works fine at low to moderate speeds, perhaps around 10-12 lineal feet per minute. Much faster and the rewinder-man won't be able to keep up, and the unwind roll of dry fiberglass will start to wander side to side and jump around a bit. That means it's time to use the air operated rewinder and dig out the cone collars to align and center the unwind roll on its arbor.

CAPTION FOR PHOTO ON NEXT PAGE: The BBW impregnator uses an arborless style rewinder, where rewind core is direct driven by an air motor on one end and aligned by a free-rotating cone collar on the other, shown here. This end's cone-collar axle can be slid in and out approximately 4" , and then locked in position, to accommodate different rewind core lengths. The cone-collar is also spring-loaded to



accommodate rewind cores with ends that are not cut-off perfectly square.

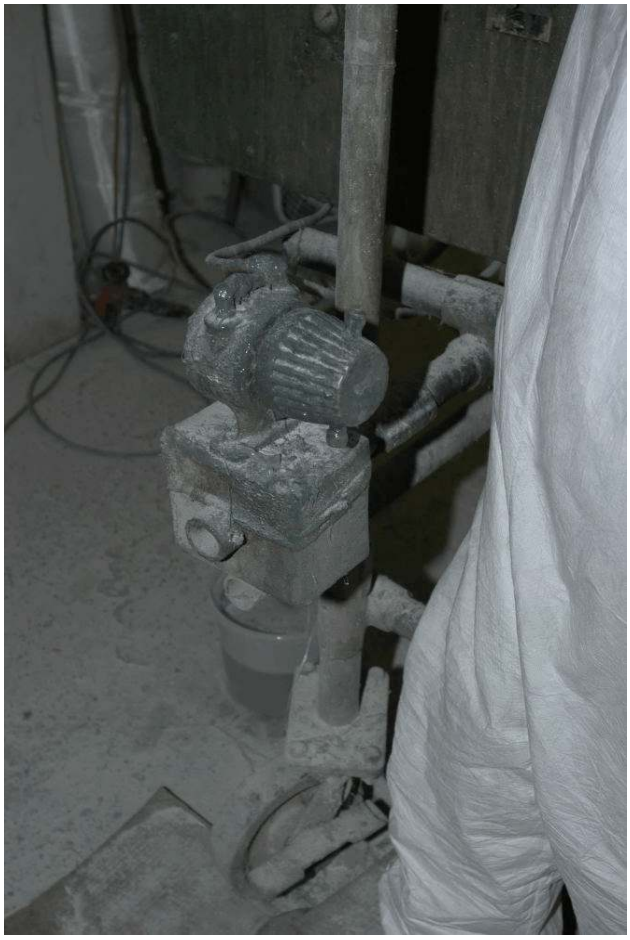
I asked Smith about using the rewinder, and he commented " We only use it for running full width materials, while laminating the hull sections and the deck. . For wide runs the impregnator crew is increased to four, with two devoted to preparing resin to feed the machine, and two machine operators. The rewound rolls of wetpreg for those parts can be quite heavy, well over one hundred pounds, so two men - the resin guys - are also required transport the rewinds from the impregnator to the mold.



CAPTION: 3" Schedule 40 PVC tubes are used as rewind cores for the impregnator's rewinder. BBW only uses their impregnator's rewinder when working with 50 and 60 inch wide reinforcements. Note the fiberglass tube-end reinforcements, to handle the high drive loads developed when rewinding long runs of high weight fabrics, which can exceed 100 pounds.

The BBW build cycle, which applies outer skin wetpregs, the core, and the inner skin wetpregs, and then bags them all together, requires rapid output and rewinding of wide material. The BBW impregnator has a 2 HP air motor roll drive, and is geared to run up to approximately 24 lineal feet per minute full speed at nominal 60" nip width.

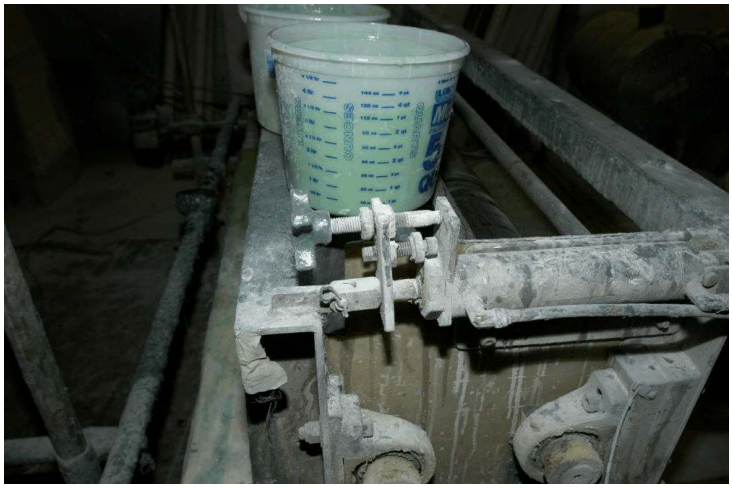
Scott Smith commented that the shop had problems in getting the impregnator and rewinder to run at high speeds. Running both the impregnator and the rewinder in the pin requires approximately 22 CFM at 100 psi air supply, and I suspect that inadequate airflow is the cause of their problem. I noted that the impregnator was fed air though a 3/4 ID flexible hose, and that the original 3/4" pipe thread size filter/regulator and lockout/tagout valve assembly had been replaced with a 1/2" pipe sized filter-regulator setup. Smith told me that " The shop's hard compressed air plumbing is inch and a quarter black iron, and the compressor had plenty of output." I suspect that increasing the bore of the machine's flexible supply hose to one inch, and reverting to 3/4" NPT specification air handling hardware will allow the impregnator to run up to full speed again.



CAPTION: Drive side of the arborless rewinder, showing the 3/8 HP air motor and the drive lugs attached to the cone-collar, which register in corresponding cutouts in the ends of the PVC rewind cores.

The air operated rewinder system on the BBW impregnator is driven by an eight vane, 3/8HP Gast Manufacturing Company (Benton Harbor, MI) air motor. The eight vane configuration stutters less than a four vane motor when stalled and at low rotation speeds. It also offers smoother startup and more sensitive tension control adjustments.

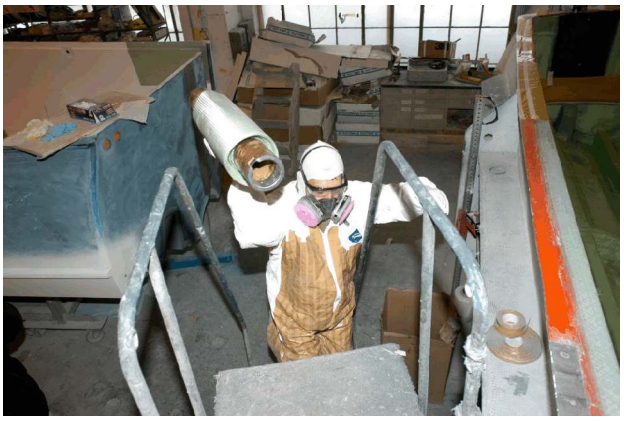
I asked Scott Smith about any modifications he would suggest to their or any impregnator, and he had some good comments. " We always have one of our skilled guys setup and run the machine. We would love to have vernier gauges or dial indicator readouts for setting the gap between the rolls, or perhaps a dial with a needle that would point to settings for specific reinforcements, such as 1208, 1808, or 2408." I built two high accuracy impregnators with dial indicator nip readouts in the late 'eighties; they looked and worked great, but the dial indicators did not survive more than a few weeks out in the laminating shop.



CAPTION: The 'nip' or gap between the rolls, is adjusted by rotating the top lugged knob and then set by tightening its knurled locking collar. The lower threaded component is a safety stop to prevent the rolls from banging together if the nip is set too tight. The horizontal air cylinder retracts to provide adjustable nip pressure, and extends to open the nip approximately 3" in the emergency stop mode.

Smith continued " I also wish that all the resin on the impregnator would just 'peel-ply' off, or that it had an automated 'rinse cycle.' Believe it or not" he added, " we

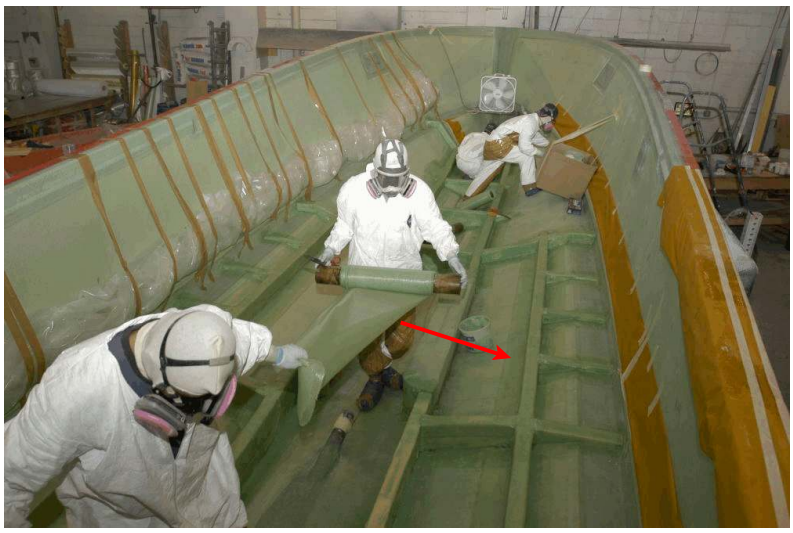
spend quite a lot of time on cleanup." Cleanup has always been an issue with impregnating machines, and one I investigated thoroughly when building these devices. Teflon coating the complete machine was possible, but very expensive, and according to the coaters I spoke to not a really practical idea. " Once they attack the Teflon coated surfaces with scrapers, " I was told, " the coating will start to fail." All exposed surfaces and components on this impregnator are fabricated from unpainted 304 Stainless Steel and anodized aluminum. Scrape away, use a sander or grinder, or get the Bernz-O-Matic torch air powered muffler chisel if necessary. A liberal application of polymeric release agent on all exposed surfaces will make future cleanup easier



CAPTION: Approximately 40 lineal feet of 18" wide wetpreg biaxial tape , wetout and rewound in about 3 minutes, about to go over the sheer flange and into the tooling to the waiting placement and tailoring crew.

The end result of The BBW impregnator operators' hard work is that the crew in the mold - which would formerly have been called the 'laminating crew' are actually now the 'placement and tailoring' crew. All the actual reinforcement wetout takes place outside the tooling - there are no buckets of resin, brushes, rollers, or bubblebusters in the tool at all, only rolls of wetpreg.

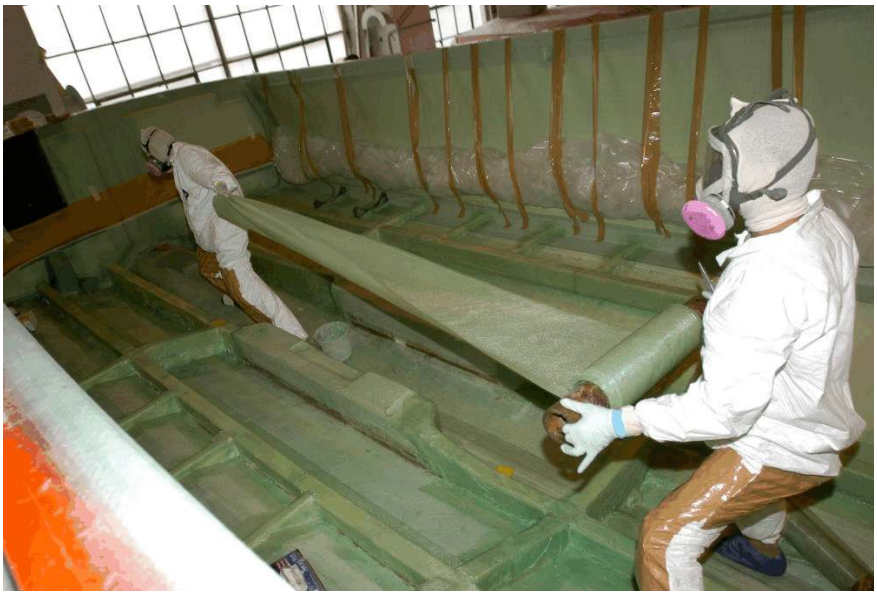
TAILORING THE TAPES Taping and tabbing is a messy, time consuming task during the assembly of most open wet layup boats. It is also a hard to control source of unpredictable weight gain, especially on big projects. The BBW laminating crew's skills in placing, tailoring and consolidating the wetpreg tapes coming from the



CAPTION: One layer of wetpreg has already been applied to the starboard stringer and had darts cut at the cross member intersections' corners. Arrow indicates the inboard ply offset.

impregnator made taping-in the urethane foam stiffeners and frames a remarkably tidy and efficient process. By carefully sequencing the application of the wetpregs and following process materials the crew avoided walking on any of the complex grid of wet laminates. Notice, by the way, the complete absence of drips on any of the panels in between the tabbed sections.

I was impressed by the speed and accuracy of the BBW crew as I watched them apply two laminates of bi-ax and mat tabbing to a stringer section approximately twenty feet long, with seven cross-member intersections. Note the nice straight edges on the tabbing, courtesy of the impregnator and pre-slit tapes. The next few photos walk you through the production sequence.



CAPTION: The next step is to unwind and position the third layer in the starboard outboard stringer. The previously applied layer was positioned with an offset, so the inboard leg was longer than the outboard , indicated by arrow.

I liked the crew's Tyvek overalls that had been thoughtfully 'resin-proofed' by the application of mylar shipping tape in areas likely to contact the wetpregs. Everyone in contact with epoxy work a Tyvek suit, a respirator and gloves.

CAPTION: Step 3 - the wetpreg tape applied to this stringer has straight edges and is easy to tailor in a neat and methodical fashion. Darts and pleats stay organized because they are not bubblebusted, just gently squeegeed into contact with adjacent wetpreg layers.

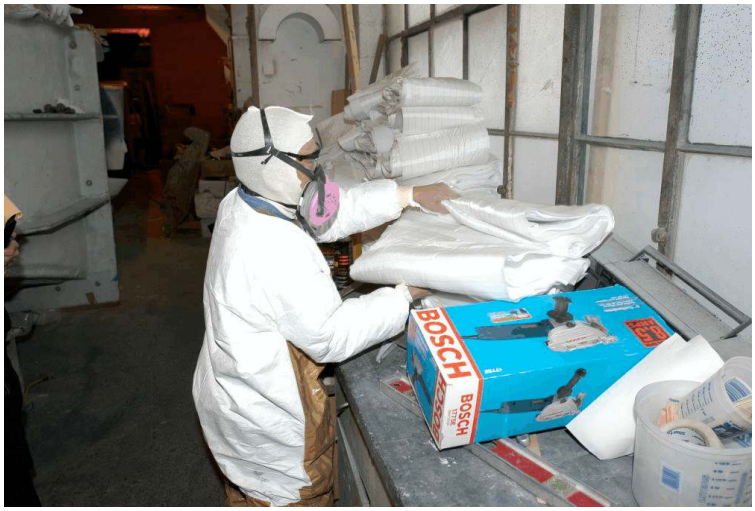
Although there are a few buckets to be found inside the tooling while the framing is being laminated, there's no resin in any of them ; they are just for scraps resulting from laminate tailoring, as shown in the adjacent photograph. Cutouts are saved, and used to fill in the 'windows' that develop at outside corner tailoring

Total time to apply three layers of laminate to approximately twenty lineal feet of stringer, including the tailoring of each ply to the seven structural intersections, was less than twenty minutes. Another taping crew, shown in the previous photo, was diligently placing and tailoring wetpregs in forward sections of the hull, and not in the way of the three man team laminating the stringer.

CAPTION: Note that this third ply is offset so the longest leg of the tabbing falls outboard of the stringer. This offsetting serves to produce the correct staggered ply drop-off schedule at the tabbing's inner and outer edges, and also a doubling of plies across the highly loaded stringer cap surface. The first ply goes down symmetrically.

PROCESS MATERIALS

Ply by ply application of wetpreg laminates in only part of the material placement, tailoring, and consolidation operation - the process materials stack has to be added too. In this case, that stack comprises white peel ply, a clear nylon perforated release film, bleeder-breather fabric, and the vacuum bag.



CAPTION: Preassembled, precut lengths of three-ply stacked and sequenced process materials were located on a bench right next to the hull mold's transom.

One component of successful vacuum bagging is planning, and accomplishing as much of the fitting of the many layers involved in advance of the start of the layup. If you look at photos 2173 & 2174 you will note that the vacuum bag is already sealed to one side of the part's inner skin, about halfway up the port topside panel. The tacky tape for the other hull side and transom has also already been applied, and is protected by brown colored plastic film tape that prevents resin contamination.

Similar forethought has been applied to the other process fabrics and films. Instead of applying each material ply by ply, BBW uses a mist of contact cement to bond the peel ply to the release film and the release film to the bleeder cloth, outside of the tooling. In the mold the three preassembled layers of process materials are applied and tailored in one step. At the moment BBW assembles the materials stack by hand on a flat layout table. Scott Smith was interested when I mentioned that the BBW impregnator, with a few tweaks like additional unwind stations, could also be used to

laminate the three process materials layers together - full 60" width - at 10 to 15 lineal feet or more per minute.

CAPTION: A light spray of 3-M Spray 77 contact adhesive was used to bond the individual lengths of process materials to each other after alignment and tailoring on the wetpreg taping in the hull.

Note that the laminator in the foreground is sitting on the engine bed as he works. It has not yet been laminated, providing a fine example of how the crew sequences the application of laminates and process materials to keep the process neat and tidy, and the workers out of each other's way. Most of the long fore and aft sections of process materials were precut to the correct length. Smaller lengths for shorter cross-members were cut off of rolls of preassembled process materials.

CAPTION:
Four plies of wetpreg went on the engine beds when all the other laminating and process materials application was completed. (Arrow shows location of handprint shown in next photo)

As the amount of framing inside the hull increased there was less and less space for the placement crew to work, and the crews gradually got smaller, but there was always a place to stand on laminate surfaces that had already cured, as in the case of the crewman sitting on the engine bed illustrated above. The four laminate layers for the engine bed, applied with offset edges to produce the correct ply drop offs and ply doubling at the cap, went down in less than five minutes, but only after all nearby laminates and process materials were in place. Each length of fabric for the bed section was cut to length from a roll of continuous wetpreg tape.

BBW's impregnator operator was paying attention to the machine's footage counter when the roll of wetpreg dedicated to the starboard engine bed region was wetout and

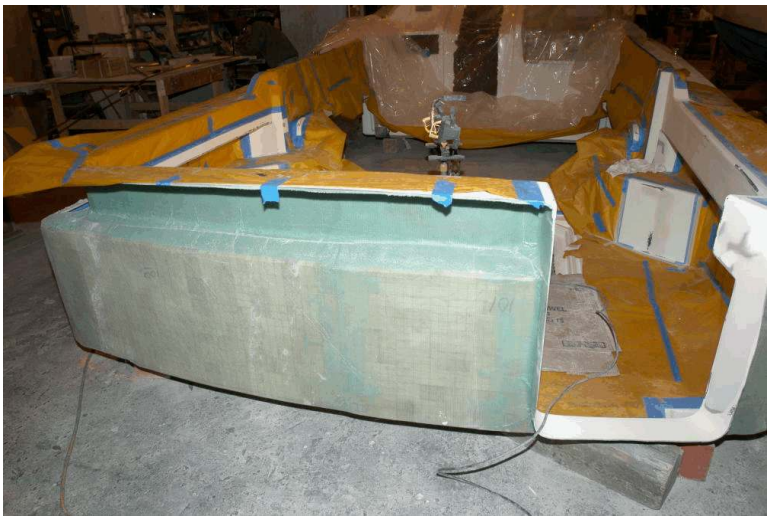
cut to length. At the end of the roll, after four lengths were cut, less than a foot of unused material remained on the cardboard core.

CAPTION: In a recent PBB article on boatbuilding with epoxy resins, I quoted Joe Parker of Gougeon Brothers about the thumbprint test they used to evaluate whether laminates destined to be vacuum bagged, which typically look resin starved, will in fact have the correct resin ratio when compressed by the bag and process materials. Check the nice void-free palmprint at the top - aft end of the engine bed laminates (at the arrow in photo # 2200) - a good sign of proper resin content.

CAPTION: The thick four ply laminate on the engine bed region is carefully consolidated by squeegeeing , but no liquid resin runs out ahead of the squeegee as it does in wet layup processes. Instead, only entrapped air is vented from between the wetpreg plies by squeegee pressure.

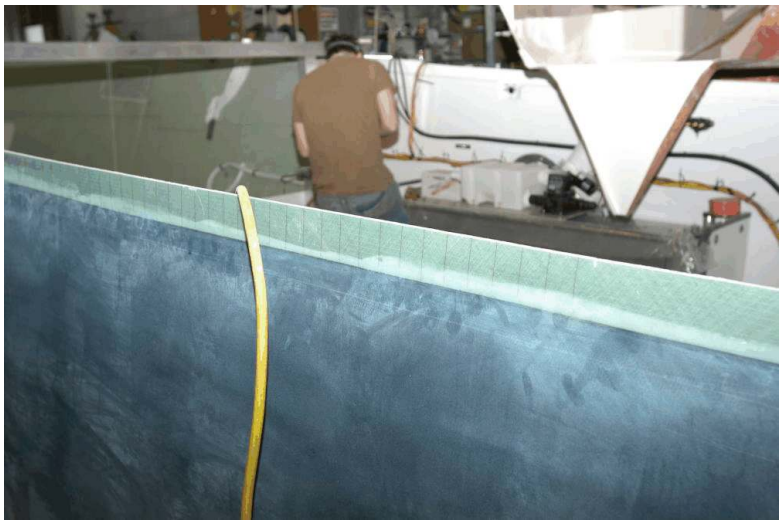
Small amounts of epoxy resin thickened with fumed silica and glass microballoons are used for filleting inside corners, and to taper-out locations with many ply drop-offs, such as the engine bed region.

CAPTION:
Moderate vacuum levels, combined with the controlled bleed of the perforated release film prevents absorption of excess resin into the bleeder. The soaked-through section is in way of the thick engine beg laminate region, and is normal.



CAPTION: BBW vacuum bagged wetpreg is well finished with little if any grinding required.

The peel ply is left in place for any areas that will have secondary bonds, such as bulkhead and partition locations, and the hull to deck joint. “ We do whatever we can to minimize grinding, “ Lindsay told me, “ and we use suck-sanders. Whenever we have to grind something, we ask ourselves why, and try to figure out a way to prevent it.”



CAPTION: Peel ply from hull laminating , pre-placed in the tooling in way of the hull to deck joint flange, is left in place until the overlapping flanges of the hull and deck parts are adhesively bonded together.

After years of one-off and custom boatbuilding both Scott Smith and Mark Lindsay are enjoying their new roles as production boatbuilders. “ We have the chance to fine-tune every aspect of building these composite boats, “ Lindsay told me, “ and to increase the efficiency of our laminating and bagging techniques. For one time projects these issues were much less critical.” Scott Smith told me “ Most of our good ideas come from the guys out in the shop and the tooling. We are constantly innovating. I am confident that we will not be building the way we are now in six months. That’s what keeps us interested.”