

Tornado Building Plans

Supplied for historical and study purposes only

These are the Houlton building plans, developed by Jerry Houlton and a community of Tornado builders around 1980. These descriptions were originally intended to be used together with the ITA/ISAF issued plans, but it is quite straightforward to build a boat without the ITA/ISAF plan sets. Jerry Houlton stopped building Tornados a long time ago, but these plans lived on thanks to Tornado afficiando Kevin Cook in the USA. Kevin has continously supplied amateur Tornado builders with plans, in a non-profit attempt to keep the wooden Tornado alive. It was trough Kevin the plans used for digitizing was sourced, during christmas 2004. Amateur buildt Tornados are an important piece of Tornado history, and these digitized plans will hopefully keep this part of the Tornado story living in the 21. century. The original idea behind having the Tornado as an olympic class, besides adding a multihull to the olympic scene, was to have a boat you could build in your backyard and go to the olympics with. And for the first years this was the way it was done, but alas, no more..

A lot has happened with the Tornado since these plans were used to produce competitive boats. Today Marstrøms Nomex honeycomb, pre-preg epoxy, autoclaved space-age boats rules the class. A carbon mast has also been added to the boat, further removing the class from it's humble olympic ideals. However, wooden boats can still be high-performers, and these plans combined with some creative thinking can produce very stiff and fast hulls. An effort to modernize amateur buildt Tornados by using a mixture of polystyrene foam bulkheads and maximum fullness hulls are discussed on the Yahoo TornadoCat list. If you, the reader, has ideas and opinions about how the amateur can produce even better Tornados, or just want to get in touch with other Tornado sailors, please join the fray at the TornadoCat forum.

In addition to the Houlton plans, an uncomplete set of russian plans from the '80s have surfaced. Some additional information can be learnt by studying these images. The russian plans was for a boat to compete in one of the olympics during the '80s.

Copyright: There has been done some research to discover wether these plans are subject to copyright or other intellectual property issues. As far as it has been possible to ascertain, publication of these plans does not infringe on any rights. Please let us know if we are mistaken. If you build a set of hulls, or a boat, please contact the ITA (<http://www.tornado.org>) to have it registered, measured and get the necessary payment information for the building fee.

For revisions, and to have experiences and facts added to the plan sets, please contact Rolf Nilsen at the Yahoo TornadoCat list.

The Houlton Boat Company

To The Amateur Builder

January, 1979

My experience in the Tornado class started in 1971 when I purchased a new fiberglass Tornado. I had sailed an old B-lion for 3 years and as soon as I saw my first Tornado I had to have one.

When I decided to replace the glass boat, it seemed like a good idea to build a wood Tornado. I had seen some of the California "Woodies" and they were good-looking, strong and fast.

I ordered a set of plans from England and after a careful review, I started asking questions of Tornado Sailors that had built their own boats. I found that many new construction ideas were being used that had not been formally written up. That's when these new construction notes actually began to take shape. There is nothing in the notes and plans that hasn't been tried and tested. The first draft copies were widely distributed and comments were sought to improve and clarify everything. Professional builders, amateur builders, and knowledgeable sailors all had good comments to add and these have been included.

If each amateur builder that uses these notes will take the time to write or call and offer his suggestions and ideas, these notes can be maintained and kept up to date. Every amateur will have worthwhile suggestions to make the boat stronger, or easier, or less expensive and others can benefit from these suggestions.

Good luck,

Jerry Houlton (sign)

6th Revision

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Recommendations for Building the Tornado

Introduction

These construction notes are written for the amateur to take advantage of the knowledge gained about the Tornado and about new construction techniques since the inception of the Tornado.

The notes are designed primarily with the idea that the amateur can build hulls as good as the professional if he is willing to take the time and care required.

From the original designers "introduction:"

"The performance of the boat is partly due to the low weight achieved by using the developed ply method of construction... Perfectly fair, round bilge hulls can be produced in a fraction of the time needed for fiberglass or cold moulded wood"

"The Tornado is basically a racing craft... As with any other class, no boat may take part in organized class racing unless it has a valid class measurement certificate. To obtain this the boat has to be measured by an Official Measurer to ensure that it conforms to the class rules..."

"The question of weight is very important, for if a boat is to be competitive its weight must be right down to the minimum allowed in the class rules. It is a common failing of amateur builders, especially with their first boat, to make too good a job and strengthen various parts unnecessarily... It is extraordinary how weight builds up when adding "a little extra" here and there... Follow the instructions! If the boat comes out under weight, correctors can be fitted"

These plans will produce a boat approximately at minimum weight. One American Tornado sailor has estimated that every 10# of weight above the minimum costs 20 seconds per hour when racing in average winds.

The plans provide only two places where water could enter the hulls; at the inspection port on the rear deck, and at the removable beam bolt holes. A silicon sealant should be used when installing the removable beam bolts to avoid water coming into the hulls. Of course if permanent studs are used, there can be no leaks here. The boat will be air tight with the ports closed. Either a breathing hole must be provided in the hulls, or the inspection port covers must be kept loosely in the hulls, or the inspection port covers must be kept loosely in the hulls whenever the boat is not being sailed, otherwise temperature variations may cause hull damage.

Adhesives, epoxy and Fasteners

The WEST system of epoxy and adhesive additives (or other similar systems) is a major breakthrough for the Tornado class in building stiffer, stronger, and longer-lasting boats that are watertight and that will not absorb moisture. A major feature of the WEST system is the ability of the epoxy to penetrate into the wood and seal it. Fasteners are not required as part of the bonding process.

These construction notes have been written to take advantage of the WEST system. The Gougeon Bros. of Bay City, Michigan can provide information and materials.

Fiberglass Cloth

Fiberglass cloth use is more expensive in the construction notes than in the original plans. Sheeting the exterior of the hull with light-weight cloth offers advantages in improved abrasion-resistance and maintenance, and will not affect a natural finish if done properly.

Tools

The tools required are:

1. Four "C" clamps with 3" throat, and 36 "C" clamps or spring clamps with 1" throat (the small clamps may be stationary clamps as available in many business offices)
2. Thirteen (13) inner tube rubber bands 2" in width
3. Saber saw
4. Electric Drill
5. High speed finishing sander
6. Block plane
7. Several Sanding Blocks
8. Protractor (Variable angle)
9. Router (optional) or wood chisel
10. Staple gun
11. The Scarrfer (Gougeon Bros.)

Spars and beams

Spars and beams are items that are beyond the talents of most amateurs. These items should be purchased. These plans were prepared using Sailcraft of Canada beams with two removable 3/8" bolts through the center of the main beam for each hull; the rear beam with one removable 3/8" bolt on the outboard side of each hull and two permanently mounted 3/8" bolts for the inboard bolt holders on each hull. Beams from any Tornado builder may be used. These same beams may be used with permanent studs instead of bolts provided that a beam strap is used on the inboard side of the main beam.

Rudders and Centerboards

It is recommended that rudders and centerboards be fiberglassed to improve abrasion resistance. They can be purchased and this is recommended until the amateur gains experience in the area.

Sails, Battens, and Trampoline

Many sailmakers recommend particular battens to be used with their sails. Most sailmakers also make trampolines.

Hull fittings

The fore-stay tangs, shroud chainplates, trampoline tracks, rudder stocks, pintles and gudgeons can all be purchased from commercial sources or from a production Tornado builder.

Materials recommendations for Hulls

Sitka spruce

	<u>Size</u>	<u>Length</u>	<u>Quan</u>
Gunwales	3/4"x3/4"	20'6"	4
Centerboard trunk			
Front inside stringers	3/4"x30mm	2'3"	2
Rear inside stringers	3/4"x30mm	2'5"	2
Bottom outside stringer	3/4"x1"	3'0"	4
Top outside stringers	3/4"x3/4"	3'0"	4
Beam chocks	2 1/2"x 1 1/4"	12"	8

These are the only spruce pieces needed if you purchase centerboards and rudders. Use good straight grain sitka spruce, at least for the gunwales. One piece 3/4"x6"x20'6" will provide for all the spruce needed.

Plywood

The only plywood recommended for hullsides is 4mm. Okoume gaboon mahogany with three equal plies. The quantity needed is 8 sheets, 4'x8'. Two 4'x32' scarfed sheets will provide for the hullsides, decks, deck beams and deck stringers. The other two 4'x8' sheets (which should be 3mm ply) will provide the conterboard trunks, bulkheads and transoms. Some of the subassemblies are made up of double thick plywood. Scarfing of the ply is easily done using the SCARFFER tool supplied by the Gougeon Bros. along with their instruction booklet.

Copper

Soft copper wire

18 or 20 gauge, 60'

Expanded Close cell

Polystyrene

One piece – 5% moisture weight gain maximum, not dissolved by epoxy	4” thick 4'x8'
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Hull fittings

Pintles and gudgeons (IYE rudder stocks)	IYE-2 each
4” circular screw-in port covers	RWO204-2
Rudder retainers	RWO76-2
Centerboard slot rubber, or 4 mil. Mylar	HBC-2
Fore-stay tangs	RWO-230 (or equivalent)-2
Shroud chainplates	RWO-229 -2
Beam bolt retainers (only if removable beam bolts are used)	1/4”x1 1/4”x2”-tapped for 3/8” bolts -6
Main beam straps and studs	HBC

Fiberglass

3 or 4oz flat weave cloth	44-48” width – 20 yards
9 or 10oz flat weave cloth	36” width – 10 yards
9oz 3” glass tape	100'

WEST System - Gougeon

5gal resin
 1gal slow hardener (206)
 4 bags - Microspheres
 1 bag - Microfibers
 1 can-small Graphite powder
 1 roller handle, 1 roller pan, 2 dozen roller covers
 3 dozen glue brushes
 1 pair – Super mini pumps
 1 box of mixing sticks, 1 large can of hand cleaner, 10 pair of disposable gloves, 2 spreaders
 WEST system manual, SCARFFER tool and instructions

Sandpaper

80, 160, 240, 400 grit, wet and dry paper as needed. Use 80 and 160 grit dry on bare wood, and 80, 240 and 400 grit wet on epoxied or painted surfaces.

Paint and polyurethane

NOTE The hulls can be finished in natural wood, or be partly or completely painted. If you choose a natural finish, you will have to coat the exterior epoxy surface with polyurethane with a high ultra-violet screen to protect the epoxy.

The paint recommend is Dupont Imron. This paint comes in clear or color and is available from automotive supply sources. It may only be applied by spraying. When spraying is not possible, we recommend Z-Spar 1015 Captains Varnish for the clear and Z-Spar monopoxy for the color. The Dupont Imron seems to produce a better and longer lasting finish.

Suggestions about the WEST System

1. Read the instruction manual on the WEST system carefully.
2. Check the pumps regularly, the dispensing pump available from Gougeon works well and will save money if rented, as you will waste less epoxy. The ratio of resin to hardener is quite important
3. for coating large surfaces use the rollers instead of a brush. The coats will be more even and less epoxy will be used. The rollers covers can be cut in half with a hacksaw.
4. Be sure to clean your hands every 10 minutes if they get epoxy on them. Use plastic gloves and keep your fingernails short.
5. Wear a face mask when dry-sanding epoxy. Wet sanding is generally recommended.
6. Epoxy coating all pieces before putting them in the hulls is much easier than coating when inside the hull.
7. White spots under the glass cloth are air bubbles. They can be dug out and filled with epoxy if the hulls is to be finished natural.
8. When sanding large epoxied surfaces, it is easier to do if the surface is wiped off with ammonia and water first.
9. To fill a gouge on a curved surface, use semi-cured epoxy, cover with polyethylene film and tape tightly to the hull until cured.
10. All fillets used in these plans are microspheres with sufficient microfibers added to keep the fillets in place. Use the thickest fillets that are practical to work with to keep the weight down.

Recommended Sequence of Construction

1. Make the deck jig (do not cut out the center) and use as a large table with saw horses for preparing the subassemblies and jigs.
2. Cut out all spruce pieces
3. Scarf and cut out all plywood pieces, epoxy coat, (except hullsides), and assemble subassemblies.
4. Cut out the glass cloth for the exterior hullsides.

5. Prepare the jigs required.
6. Complete the deck jig.
7. Complete the bow-spacer jig.
8. Prepare bow-spacers
9. Begin hull construction.

Jigs and Subassemblies

Deck jig

Use 3/4"x3/4' stringers of any material and use 3/16 or 1/4" plywood for the flat surface. The stringers need not be scarfed if small blocks are used next to the butt joint. The plywood should be scarfed.

1. Construct a panel 21'6"x2'6" with the stringers epoxied around the outside edges
2. Draw out the deck plan but do not cut out at this time.
3. Support the deck jig with sufficient saw horses to serve as a table until all jigs and subassemblies are made. Be sure the surface is flat.

Spruce pieces

Cut out the spruce pieces according to the sizes on the materials list.

1. Gunwales
2. Centerboard trunk stringers
3. Beam chocks – epoxy coat all surfaces. These chocks may be made by bonding two 3/4" pieces together and cutting to 1 1/4".

Hullsides

Scarf two 4'x32' pieces. It is very important that the hullsides are accurately measured and that the curve along the keel is fair. Use the plans to locate the hullside on the 4'x32' sheet of plywood. Avoid walking or kneeling on the ply to avoid dents. Work on a flat surface and draw out the shape for the first hullside, it will be the template for the other hullsides.

1. Construct the datum line with the aid of a tightly stretched string. This should be raised sufficiently at each end to prevent it touching in between. Mark points beneath the string and join them up with a straight edge.
2. Mark off stations 1 to 20 along the datum line with a STEEL measuring tape. (Note: owing to the curvature which the sides will have after assembly, these stations will not agree with those used for measurement of the completed hulls).
3. Locate point B (the bow tip) at the exact distances indicated from A and C. Then draw the vertical BA.
4. Mark off stations 2 to 20 along the line BX and then draw the station verticals
5. Mark off all the offsets using a STEEL rule marked in millimeters
6. Using a straight and uniform batten, draw a fair curve through the gunwale points and through the keel points from station 3 ft. to station 20 ft. 6 ins. Complete the bow with a thin batten.
7. Cut out oversize and sand down to the line
8. Use this first hullside as a pattern to draw out the shape of the other three. Do this on a flat surface, weigh down the pattern to prevent movement, and use a sharp pencil or ball point pen.
9. Cut each out oversize and sand down to the line.

10. Select from the four hullsides the outboard and inboard sides of the starboard and port hulls and label on the inner surfaces
11. Accurately transfer stations 2,5,10,14,16 and 20 to inside surfaces and edges of these three hullsides from the first, using a ball point pen.
12. On the inner surfaces of each hullside construct the positioning lines for the bowspacer, using a ball point pen.
13. On all surfaces draw a line around the keel 1 3/4" from the edge. On one outboard surface of each pair of hullsides draw a line around the keel 3/8" from the edge. Use a pencil.

Exterior Glass Cloth

Use a hullside as a template and cut out 4 pieces of cloth 2" oversize all around. Roll up and set aside.

Centerboard Trunks

1. Cut out the ply for the trunks using the 3mm ply to the pattern shape of the trunk side. Do not cut out the pivot slot. Mark one trunk side, cut out, and sand down to the line. Use the first side as a pattern for the other three.
2. Determine two port and two starboard side. Coat the inner surfaces with graphite and epoxy (about 20% graphite powder), re-coat and allow to cure. The graphite powder will make the surface smoother after sanding.
3. Sand smooth using 80 and 240 grit dry paper. A finishing sander is fine.
4. Apply the first coat of epoxy to the outer sides, re-coat and staple spacers to sides. Use short staples that will not extend through the sides. Allow to cure and remove staplers
5. Match and mark two sides together, clamp with inner surfaces together, drill the 25mm pivot hole and cutout to the top of the trunk. Repeat for the second trunk. A router pattern may be made for the cutout to make this step more accurate.
6. Apply first coat of epoxy to spacer and cover, re-coat and staple cover to spacer. Allow to cure, remove staples, and coat covers with two coats.
7. Notch out the top stringers for the pivot slot, coat each surface with epoxy and clamp the top stringers to the trunk sides. The top stringer should extend some 50mm forward on the front of the trunk and 25mm aft. Be sure the notch out is deep enough to allow the trunk side to cure flat.
8. Attach the bottom stringers to the trunk sides. Coat each surface with epoxy and clamp together. Be sure the trunk sides are flat and allow to cure.
9. Prepare the centerboard template using the centerboard pattern and your centerboards. The shape of the centerboard may vary slightly from the pattern (usually fore-aft location of the handle) depending upon the manufacturer. The pivot hole is determined using the pattern, matching the pattern and the centerboard template below the waterline. Drill the pivot hole.
10. Lay the centerboard template on a trunk side with a piece of pivot tube in place. You will find that the centerboard template waterline will extend about 13mm below the trunk side. You can now determine the correct locations for the internal stringers. With the centerboard template in the down position and the waterline of the template the same distance below the trunk side for and aft, mark the top and bottom locations of the rear stringer onto the trunk sides. The handle should touch the stringer at the top and clear the board at the bottom by 6mm when the board is in the up position. In the up position with the board inside the trunk at the rear by 6mm, the top of the board should touch the front stringer. At the bottom the stringer should clear the board by 5mm. Mark the locations for the front stringers on the

trunk side. Repeat this step for the one side of the other trunk. You are now ready to attach the stringers to one side of each trunk. The stringers should extend 6,, or more above and below the trunk side after attachment.

11. Coat the stringers and trunk side with epoxy, re-coat, and clamp in place. You will be doing one side of each trunk. Be sure the trunk is flat and allow to cure.
12. Lay each centerboard in the trunk sides with the stringers installed. Lay a straight edge across the stringers and determine if the vertical stringers need to be planed down. The board should clear the trunk sides with minimum clearance (1-2mm). Plane down the stringers if necessary. Mark each centerboard and trunk port and starboard in case one centerboard is thicker than the other.
13. Align the matched trunk sides together and be sure that the pivot slot is aligned at the top and the bottom. Mark the second trunk sides carefully. Coat the stringers and the second trunk sides with epoxy, re-coat, and clamp together. Lay flat and allow to cure.
14. Plane toe bottom stringers to fit the keel. The approximate angle will be 140 degrees but check the inner keel angle and plane in stages. You can check the fit by looking for light on the inside of the trunk.
15. Epoxy coat the bottom stringers when the fit is good. Allow to cure.
16. Coat all outside surfaces of the trunks with two coats of epoxy. Allow to cure. The trunks are now complete and ready for installation.

Main Bulkhead

1. Prepare a plywood template from the plans and use to make a second bulkhead. Cut out oversize and epoxy coat both bulkheads to other pieces of double thick ply. Weight down with a heavy flat object or staple together.
2. Allow to cure.
3. Cut out and sand down to the line.
4. Epoxy coat both bulkheads, two coats.

Middle Bulkhead

1. Prepare a plywood template and the bulkheads as done for the main bulkhead. Double thick ply.

Rear Bulkhead

1. Prepare to fit after the hull is shaped, double thick ply.

Transom

1. Prepare a plywood template from the plans as was done for the bulkheads.
2. Make two transoms to 8mm ply. Coat inner surfaces with two coats.

Deck beams

The deck beams on each side of the beam channels are double thick ply.

1. Prepare a plywood template from the plans.
2. Cut out 29 deck beams for each hull (total 58). Cut the top curve slightly oversize and sand down to the line. Deck beams numbered 1 through 5 for each hull can all be cut out to the approximate #5 size. All the rest should be cut out to full size.
3. Number the deck beams according to the plans. Notch out the deck beams for the deck stringers. The notch should be 4mm wide and 25mm deep. This can be done by clamping a number of deck beams together and cutting with a radial saw, table saw, or saber saw.
4. Prepare 8 double thick deck beams for each side of the beam channels. Coat with epoxy and staple together or weigh down with a heavy object. These are made from 16 of the deck beams previously cut out.
5. Epoxy coat all deck beams on each side and the bottom with two even coats.
6. Allow to cure.
7. The deck beams will be individually cut down to size when they are fitted to the hulls.

Deck Stringers

1. Cut out six 1860mm and six 2350mm deck stringers 25mm wide. Cut out evenly to avoid sanding later.
2. Epoxy coat on each side and the bottom with two even coats.

Transom jig

Cut out according to the plans

Pit Prop and Tie (Station 16)

Cut out according to the plans

Bow jig

Prepare just prior to its use. Refer to construction notes.

Complete Deck Jig

1. Cut out the center of the deck jig accurately, following the general procedures used for making the first hullside. Also make the cutouts which enable the deck jig to be tied to the hull.
2. Epoxy and clamp the inner stringers up to, but not overlapping the edge.
3. Epoxy and clamp on the various cross pieces.
4. Allow to cure.
5. Sand the inner surfaces smooth.

Bow-spacer jig

1. Use the center cut-out from the deck jig.
2. Draw the upper and lower sides according to the plans. Cut out oversize and plane down to the line.

3. The end block should be slightly deeper than the 4" foam. Epoxy and clamp in place. Be sure the bottom side is exactly central under the top side.
4. Allow to cure.

Bow-Spacers

1. Cut out two pieces of foam to the maximum width of the bottom of the bowspacer jig.
2. Epoxy coat a small piece to the each bow section to secure the length required in the bowspacer jig.
3. Allow to cure.
4. Place the foam block in the jig and weight down or clamp together and cut out slightly oversize with a hand saw.
5. Sand down to shape with a long sanding block.
6. If it moisture absorbtion rate is 5% or less, there is no need to epoxy coat the foam block.

All subassemblies and jigs are noe prepared.

Construction

A: Prepare hullsides from wiring and fiberglassing, and epoxy on gunwales.

I assemble both hulls at the same time, with the exception of the time that each hull is the deck jig.

Subassemblies

Both pair of hullsides

4 gunwales

1. Lay each pair of hullsides accurately together on a flat surface with the 3/8" keel line up, and weight down to prevent movement. Drill the 1/16" holes starting at the bow; 4 at 1" intervals, 2" intervals to station 2, 4" intervals aft, and 1" intervals the last 12". Be sure that one hole is exactly at station 20.
2. Lay the hull sides flat, and epoxy and clamp gunwales to the hullsides, making sure they are on the inside surfaces. They should butt right up to the edge of the hullsides. Use all 40 clamps, 6" apart without fasteners, If clamps are not available, the ply can be stapled to the gunwales.
3. Allow to cure. Remove clamps or pull the staples out.
4. File and sand off the excess epoxy on the top of the gunwales.

B: Complete preparation of hullsides, wire up along keel and set up for fiberglassing.

Part 1. Fiberglassing along inside of keel.

Part 2. Subassemblies

Transom jig

44 3/8" (1127) 'pit prop'

Tie for station 16

Variable angle (protractor)

1. Taper the gunwale down to the point at the bow. Start the taper 250mm back. At the bow the gunwale should be plane right to the second ply.
2. Using a sanding block or plane, radius the INSIDE corners along the full length of the keel to the shape shown. From station 2 to the bow sharpen the inside surface sharply, trough 1 ply and back 13mm.
3. On both inside surfaces apply 50mm masking tape round the keel from station 2ft to the station 20ft 6in at a distance 45mm in from the edge, butting up to the guide line previously drawn.
4. Lay the inside surfaces of the hull sides together and LOOSELY joining the keels by passing 100mm lengths of copper wire trough the holes and twisting the ends together.
5. Insure that the hullsides are exactly level fore and aft, then push the gunwales apart and insert the 1127mm pit-prop between them at station 12.
6. Close the gap along the keel by twisting up the wires with a pair of pliers. Try to obtain a uniform 'corkscrew' effect by pulling as well as twisting. This helps prevent one wire simply winding round the other. To not tighten completely at this time.
7. Fit the variable angle to the outside of the keel at station 12 and measure the angle obtained with the protractor. Move the pit prop fore-aft by trial and error to obtain 142 degrees. (1127mm is nominally correct). If the pit-prop is removed, leave another in its place to prevent the hullsides closing up and straining the wires.
8. Wire on the transom jig. At the keel it should be 25mm aft of station 20. Tack a batten diagonally across to a gunwale to keep the transom jig perpendicular, if neccesary.
9. At station 5 install a clam to each gunwale. Loop strong string trough the clamps and pull inwards to obtain exactly 635mm across the gunwales measured to the outside of the ply.
10. At station 16 clamp the tie across the gunwales to set the angle at the keel to 148 degrees. Measure the angle with variable angle as before.
11. Check that all the wires are tight and that the two sides butt together evenly along the keel.
12. The wire will have formed into raised loops along the inside of the keel. Push the middle of these loops down into the V. (But not so far that a gap is opened between the hullsides). After this re-tighten the wires if they have loosened, and recheck the butt along the keel.

Part 2 Subassemblies

NOTE: The inside keel is filleted and glassed from station 2 to exactly 30mm in front of station 20. Avoid spilling resin on the hullsides as set it stiffens the ply, causing uneven spots when the hullsides are bent into the deck jig. (Even if most of the resin is wiped off). On no account fiberglass in front of station 2.

13. Support the hull in at least 3 places to insure a fair shape to the keel and balance horizontally.
14. Brush epoxy over the area along the keel between the maskin tapes from station 20 to exactly 30mm in front of station 20.
15. Cut a 25mm mixing stick square across the end and use to fillet the keel. The idea is to fill the angle at the keel with the fillet mixture and then to apply the 3" glass tape. The fillet will be flat across the top.
16. Roll up the 3" glass tape and soak for a few minutes in epoxy, squeeze out the excess epoxy and lay the tape centrally at the keel. Use three pieces and to not overlap, just butt them together.

17. Remove the masking tape. Re-check the butt along the keel.
18. Allow to cure.

C Fiberglass along the outside of keel

NOTE: The outside of the keel is fiberglassed with one layer of glass tape, just as the inside was done. Use the 3" tape. Work with two pieces of equal length and butt together, do not overlap.

1. From station 2 to the 12mm aft of station 20 only, cut the wires off flush with the hull. Do not, however, cut the wires securing the transom jig.
2. File the copper wires and sand down the sharp edges along the keel. Do not overdo the sanding however as the strength of the keel will be reduced. A nicely rounded shape is desirable.
3. Apply masking tape 45mm from each side of the keel from station 2 to the transom.
4. Brush epoxy over the area along the keel between the masking tapes. Fill any voids at the keel with fillets.
5. Lay the pre-soaked and squeezed out lengths of 3" tape centrally along the keel from station 2 to 13mm aft of station 20.
6. Allow to cure.

D Push gunwales inwards and place within deck jig.

Fit transom

<u>Subassemblies</u>	<u>Materials</u>
Deck jig	Rope or strap clamps
Transom	
Adjustable angle (protractor)	

Note: The fiberglass along the keel must be fully cured before proceeding with this operation.

1. Remove the transom jig and other cross pieces
2. Saw off the rear end of the assembly 10mm aft of station 20. Take care not to damage the ply at station 20. Sand the edges smooth. NOTE: If the aft section is not cut away, there will be a dangerous stress concentration at the end of the fiberglass (inside) when the ply is bent into shape.
3. Place the deck jig reverse way up on the ground, or on multiple sawhorses, propped up 25mm on both ends to accommodate the reverse sheer of the hull. (I.e. The curve along the gunwales in side view.) NOTE: The next steps are the most dangerous in the hull construction due to the possibility of the plywood splitting. Step 4 will remove the danger.
4. Turn the assembly gunwale up and wet with water along the inside of the keel line 6" up, from station 2 to station 20. Aft of station 18 wet to the gunwales. Turn the assembly keel up and wet 6" on each side of the outside keel from station 2 to station 20. Aft of station 18 wet to gunwales. Use a sponge or roller and repeat several times to allow the water to thoroughly penetrate the wood. Proceed with step within a ½ hour.

5. Lay the assembly keel uppermost over the jig and with one person on either side push the gunwales into the jig working from bow to stern. Push the bow forward into the jig until it is tight. It is very important that the forward portion doesn't spring out again when nearing the stern as the ply at the transom will be put into undue strain. To prevent this, a third person should tie the jig to the hull at the front, center, and rear in turn as soon as the gunwales are inside the jig at those positions. A better way to secure the jig to the hull is by using adjustable strap clamps. NOTE: The transom is under the greatest strain. As this part of the assembly is pushed into the jig, the two people should hold the keel up to keep a fair curve in the transom while the third person installs a clamped stick across the gunwales and up to the keel 3" forward of station 20 to maintain a fair curve while the ply dries.
6. Make certain the 3 strap clamps are tight. Then turn the hull and deck jig right side up. Support the deck jig with saw horses parallel to the hull's sides about 3' high and close to the hull. Be sure to maintain the curve of the gunwales by keeping the bow and stern about 1" lower than the center. You may support the keel from the floor at station 10 and station 14 to relieve some of the hull weight.
7. Check that the tip of the bow is as forward as it will go in the jig.
8. Check that the hull is free of twist by placing a batten across the gunwales near the transom and another at about station 8. Make sure the battens do actually touch the gunwales and not just excess epoxy or the deck jig. Sight from the bow and line up the two battens which should, of course, be parallel. You may use a level also to check for twist at about every 4'. One person at the transom and one at station 8 can force out any twist between them. When this has been done, clamp the gunwales to the jig at station 16 to prevent further movement. Do not clamp anywhere else as the gunwales will be at an angle to the jig and clamping will force in the wrong shape. If gunwales don't touch the inside of the deck jig, force apart and put in sticks to insure the correct shape.
9. Looking down on the deck jig and hull, apply 1" masking tape where the hull and deck jig meet to avoid epoxy drips that would make it difficult later to remove the hull from the deck jig.

Part 2

Note: Read the class rules carefully before doing step 1.

1. Mark the top of each gunwale 2 1/2" in front of station 20 and cut away the gunwale aft of this. (This distance is only correct for the double ply, 8mm transom recommended.) The cut should be raked at the same angle as the transoms which is 100 degrees to the gunwale. It can be marked with the adjustable angle. After the saw cut, chisel off the gunwale aft of the saw cut carefully in small sections to avoid damage to the ply.
2. The transom has been made slightly wider than the design width just at the deck level to accommodate small errors in the deck jig. By trial and error, sand down the transom equal amount on each side, blending in with the correct shape until a push fit, but not a free fit is obtained at the gunwales. The transom should bear against the ends of the gunwale stringers, and the aft side of the transom should be 13mm in front of station 20 at the keel. NOTE: The natural shape of the hull will be considerably different to the transom shape, and the transom will have to be forced down quite hard to make the hull-sided touch all round.
3. Clamp a suitable piece of wood (3" wide) across the top of the gunwales immediately in front of the transom. Force down the transom with a clamp at each side of the transom and slowly and evenly clamp down until the fit is tight. NOTE: Be sure the transom area ply has dried thoroughly before proceeding to step 4.
4. After insuring that the transom fit is good, make a pencil line inside and outside where it touches the hull. Be sure to leave the transom clamp in place to hold the hull shape, and

- remove the transom.
5. Coat the edges of the transom with epoxy and also between the pencil lines. Allow sufficient time for the epoxy to penetrate the wood (at least 15 min.).
 6. Make a medium fillet mixture. Coat the surface between the penciled lines and coat the transom edges. Install the transom again and fillet around the transom on the inside of the hull. Look at the outside surface and fill any small voids with the fillet mixture.
 7. Remove temporary clamp after transom is installed.
 8. Allow to cure.

E Fit main and middle bulkheads Part 1

Fit beam chocks

Prepare glass cloth

Fiberglass inside of bow Part 2

Install bow-spacer, glass cloth, and main and middle bulkheads

Subassemblies

Materials

Main bulkhead

3" glass tape

Beam chocks

10oz glass cloth

Middle bulkhead

Bowspacer

Part 1

1. Place the middle bulkhead in position at station 14. The curve along the top should meet the gunwales at the top inside edge. The fit should be snug even though the hull will be glassed when the bulkhead is installed.
2. Check the fit of the main beam chocks with the main bulkhead in place. It should be snug even though the hulls will be glassed when the bulkhead is installed. Prepare 2 clamping sticks the proper length to hold the beam chocks against the hull sides.
3. Prepare the glass cloth to be installed. The hulls will be fiberglassed according to the plans. In addition, prepare the second layers of 10oz cloth.
4. Cut the 3" glass tape to fit from the top of the bow to station 2 on the inside of the keel.
5. Fit the two parts of the bow jig (made at this time) to the bow. Use the bow itself as the template and make the bow jig of 3/4" plywood. Do not install at this time. **NOTE:** Preparation is now complete for the epoxy steps. The next steps must be done without delay to avoid the epoxy hardening until all of the hull shaping components are installed. Three people are really necessary to get Part 2 done within 2 hours. If possible, turn your heat down to 60 degrees to delay the epoxy hardening.

Part 2

1. Glass and fillet around the inside of the bow with 3" glass tape as was done for the rest of the keel. Look at the bow from the outside and determine if you have a fair curve within 4" of the bow. If not, push small (1"x2") pieces of foam into the bow from the inside to get a fair curve. If the ply pieces don't touch to station 2, tighten the copper wires. If the bow is not perfectly straight (it's not likely) install the bow jig at this time. This step is difficult because

it is hard to keep hollows from occurring. Place the center of the bow jig at the edge of the ply and clamp easily to straighten the bow. Clamp at 6" intervals.

2. Coat the hull-sides with epoxy (one coat) from bow to transom on both sides. Use a 1" brush for the bottom of the gunwales and a roller for the rest.
3. Apply the first layer of 10oz glass cloth from the rear of the bowspacer line to transom on both hull sides, and below the bowspacer. Wet in with epoxy and squeegee dry. The glass cloth should butt up against the bottom of the gunwales.
4. Apply a good second coat of epoxy to the wood below the bowspacer.
5. Epoxy coat the sides of the bowspacer and insert it holding close to the top of the hull until it is forward to the proper position. Push the bowspacer down to the position line marked on the hullsides. Do this step carefully to insure that the bowspacer does not slip below the line. Even 1/8" below the line will alter the hull shape and cause a hollow in the hullside to occur.
6. Place the main bulkhead in position at station 10. Apply a medium fillet mixture to one side of each beam chock and wedge them into position under the gunwales. Wedge the beam chocks apart with the two clamping sticks previously prepared. Check the outside of the hull to be sure that the surface is fair.
7. Install the middle bulkhead from the front and push in gently to station 14.
8. Allow to cure.

F.

Prepare rear bulkhead

Install rear bulkhead and beam chocks

Fiberglass above the bowspacer

Fillet bulkheads and install second layers of glass cloth

NOTE: The original building plans do not provide for a bulkhead at the rear beam location, Many US Tornado sailors recommended a rear bulkhead and it is included in this section. It may be installed when the hulls is in the jig or after the hulls is out of the jig.

1. The rear bulkhead may be installed with rear beam chocks as was done with the main bulkhead or the beam chocks may be installed first. In either case, make up a rear bulkhead of double thick ply. The location of the bulkhead is at the center of the rear beam. Epoxy coat with two coats after cutting out the lightening hole.
2. Allow to cure.
3. Install beam chocks and rear bulkhead with a medium fillet. The hull will be curved at the beam chock location so use a good quantity of fillets to fill any voids between the hullsides and the beam chocks. Use clamping sticks to hold in place while curing.
4. Fiberglass the interior of the hulls forward of the main bulkhead above the bowspacer to the gunwale. Use 10oz glass cloth on both sides of the hull. Start the cloth at the bottom of the gunwales and overlap the bowspacer by 25mm. The cloth should be installed from station 2 and overlap the glass cloth aft of the bowspacer by 25mm.
5. The bulkheads were installed without fillets, and now is the time to add the additional strength. Apply medium size fillets to both sides of the main, middle, and rear bulkheads and around the inside of the beam chocks and the transom, then install the second layers of cloth overlapping the bulkheads by 25mm.
6. Coat all wood surfaces to have two coats of epoxy.
7. Allow to cure.

C. Fit deck beams

Install deck beams

1. Fit each deck beam from the bow to the main bulkhead and from the middle bulkhead to the transom. The fit does not need to be exact as the deck beams will be installed with fillets.
2. Install all of the deck beams previously fitted. Use a fairly thick mixture and staple in place. Refer to detail drawing to show how staples are installed. Be sure to fillet the deck beams to the bottom and sides of the gunwales.
3. Allow to cure

NOTE: Remove the hull from the deck jig and place in cradles deck side up. Complete the second hull up to this same point.

H. Finish transom and bow Part 1

Install beam channel deck beams

Fit centerboard trunk Part 2

Install centerboard trunk Part 3

Part 1

1. Cut off the ply aft of the transom and sand smooth.
2. Finish the bow exterior by filing, sanding, and glass taping as was done for the keel. Use one layer of 3" glass tape at the bow.
3. Allow to cure.
4. Measure from the bow and locate the aft edge of the main beam and the front edge of the rear beam. Draw a line across the gunwales perpendicular to the centerline of the deck. These dimensions are very important, read the class rules and be careful. Use a T square to mark the reference points across the hull, refer to the deck structure plan.
5. Install the main and rear beam channel deck beams, refer to the deck structure plan. Do not install the bottom of the channel yet, as you will want to reach into the hull at the beam location later. Cut out the deck beams slightly oversize and sand until the fit is snug. Coat ends with epoxy, re-coat for absorption, and fit them into place. You may need to use staples to hold the deck beams until the epoxy cures. Fillet on the outside of the channel.
6. Allow to cure.

Part 2

NOTE: Fitting the centerboard trunk must be done carefully to insure that the boat will measure correctly. The trunk must be located so that the following conditions will exist after it is installed.

- A. Vertically aligned in the hull at deck and keel centerline.
- B. Aligned in the fore-aft plane so that the leading edge of the centerboard on the outside of the keel will fall within the measurement tolerance.

1. Mark the deck centerline on the top of the aft channel deck beam.
2. Draw a clearly visible line at the inside center of the keel from 2" aft of the main bulkhead to

1" forward of the middle bulkhead. To insure that this line is in the center of and parallel to the keel line, drill two small (1/16") holes vertically up from the keel. These holes will be filled when the trunk is installed.

3. The way to find the exact location of the leading edge of the centerboard on the outside of the keel is to prepare the bow measurement template from the plans and measure the distance aft. Make a mark on the outside of the keel in the center of this rule's tolerance.
4. Drill a 1/16" pilot hole through the keel into the hull. This is the reference point necessary to fit the centerboard trunk.
5. Measure the distance from the front of the bottom outside stringers to the leading edge of the centerboard template when fitted in the trunk. Add 5mm for the angle aft through the keel of the centerboard. This total measurement is the distance forward of the reference point that the front of the stringers must be placed to locate the trunk in the fore-aft plane. Make a mark in the hull.
6. Cut off the front ends of the top stringers until the bottom stringers fit the mark on the keel.
7. The trunk is now fitted and ready to install.

Part 3

1. The trunk is bedded down on a layer of medium fillet. Fillet the keel starting 13mm up from the keel center. Coat the top front stringers, the aft deck beam, and the bottom of the trunk with epoxy and place in position. Look down inside the trunk and align the trunk to the center line drawn on the keel. Be sure the trunk is forward to the aft main beam deck beam. Clamp the trunk down to the keel with clamping sticks attached to the gunwales at the front rear of the trunk, use sufficient pressure to hold the trunk firmly to the keel without distorting the shape of the hull. Clamp the top front stringers to the deck beam at the centerline of the deck beam. Verify that the trunk is still aligned to the keel center line after clamping is complete. Be sure that the aft end of the trunk at the deck level is in the center of the hull.
2. Allow to cure.
3. Make a medium fillet mixture and bed in around the trunk and between the stringers on both ends of the trunk.
4. Prepare a piece of spruce to go between the rear of the trunk and the middle bulkhead. Coat with epoxy, fillet, and push into place to attach the trunk to the bulkhead.
5. Fit and install the deck beams from the rear of trunk to middle bulkhead.

NOTE: Prepare a 4mm ply deck template with a concave edge using the building plans. This will be used for beveling the gunwales and for sanding the deck beams and deck stringers before decking.

I. Bevel gunwales and sand deck beams

Install chainplates

Install deck beams to trunk sided

Step 1

1. Plane down the outside edge of the gunwales to continue the curve of the deck beams. Use the template to insure the correct shape. Use a long sanding block to finish shaping the gunwales and all deck beams.
2. Locate the exact center of the forestay tang on the inboard side of each hull and mark. The

dimension to the center of the cut is 1992mm forward of the aft edge of the main beam, this allows for the aft rake of the tang.

3. Drill a series of holes from the outside of the hull to the inside at the approximate angle that the tang is to enter the hull and file the opening smooth. This opening should be 1/8" below the sanded gunwale. The actual exit angles are 16 degrees aft and 136 degrees from the vertical of the hullside at the exit point.
4. Locate the point on the opposite side of the hull that is a continuation of the tang at the correct angle of entry and mark.
5. Prepare a strip of wood that the tang is to be bolted to and mount in position just below the tang entry hole and across to the other side of the hull. Use a liberal amount of fillet under the gunwale and on to the other side of the hull to secure in place. Two strips of 4mm ply, 3" wide (epoxied together) will suffice or use one piece of 1" square sitka with 4mm ply triangular plates on both sides of the hull.
6. Allow to cure.

Step 2

1. Locate the exact center of the shroud chainplate on the outboard gunwale and mark. Read the class rules carefully. The dimension to be used is 715mm aft of the aft edge of the main beam.
2. Drill a series of holes through the top of the gunwale next to the ply at an angle of 8 degrees forward of the perpendicular to the gunwale. File the opening smooth and insure that the shroud chainplate will fit.
3. Epoxy three strips of ply (6", 4", and 2") (the length of the chainplate) together and mount to the outside hull surface at the shroud location. The purpose is to shape the pieces to the contour of the hull. Use an innertube rubber band to hold in place until the epoxy is cured. Protect the exterior hull surface with a piece of polyethylene.
4. Allow to cure.

Step 3

1. Fit forestay tangs in place, drill and bolt loosely. The center of the attachment hole should be 300 from the hullside on top.
2. Remove, wet thoroughly with epoxy, and re-assemble. Tighten bolts securely.
3. Coat the entire assembly with epoxy, bolts included, and fill any voids where the tang enters the hull with epoxy.
4. Allow to cure.

Step 4

1. Remove shroud chainplate support pieces from hull sides.
2. Use a router or chisel and notch support pieces to fit chainplates.
3. Fit chainplates to support pieces using countersink head 1/4" bolts. Countersink them into the chainplates. The center of the attachment hole should be 30mm above the gunwale. Assemble loosely and fit into the hulls with the correct exit angles. The exit angles are 8 degrees forward from vertical, and 75 degrees inboard from the deck at the exit point. Remove the chainplate assemblies, disassemble, epoxy coat and re-assemble, tightening the bolts securely.
4. Set assemblies aside and allow to cure.

Step 5

1. Use a liberal amount of medium fillet and mount shroud chainplates in hull. Use a large clamp just below the gunwale and one or more sticks below to hold in place. The assembly should butt up against the gunwale. Do not distort the hull shape when clamping in place.
2. Allow to cure.

Step 6

1. Plane the top of the trunk to continue a fair line to the top of the deck beams. Use the deck template previously made.
2. Fit the deck beams to the trunk sides and fillet into place. Be sure to avoid altering the longitudinal shape of the top of the trunk.
3. Allow to cure.

J. Cut out keel trunk slot Part 1

Fit beams

Install channel bottoms Part 2

Part 1

1. Locate the ends and sides of the trunk slot at the keel by drilling pilot holes. Drill a 1" hole at each end of the trunk. Draw lines parallel to the inside of the slot and cut out with a saber saw. File and sand the edges smooth. NOTE: The beams are fitted before the decks are installed.
2. Set up the hulls in preparation for fitting the beams so the following conditions exist:
 - A. Deck centerlines are equidistant at bow and stern and within the measurement rule tolerance. Measure at the forestay tang and just aft of the rear beam.
 - B. The diagonals from the bows to the sterns are equal.
 - C. A straight edge laid across the hulls at the bow and stern is horizontal. Use a good level. Do not use the main beam as a straight edge as it will have a slight curve due to the pre-tension of the dolphin striker.
 - D. Set both hulls upright by dropping a plumb line through each centerboard trunk just aft of the bottom front edge of the trunk. Suspend the plumb line at deck level exactly on the deck center line. This should be exactly at the trunk center. Look along the keel and set the hulls so that the keel is aligned to the plumb line. Measure the keel centerline separation just aft of the main beam and be sure that the difference, if any, is within the rules tolerance. NOTE: this entire hull setup procedure is slow and tedious, so to be sure that you will not need to do it again after cutting out the beam cutouts, make whatever jigs that you can to hold the hulls rigidly in place.
3. Make a re-check of all of hull setup.
4. On the inboard side of both hulls at the main and rear beam locations, draw lines parallel to and exactly 23mm below the edge of the gunwale. This dimension allows for 5mm for the deck and its installation.
5. Determine the precise fore-aft location of both beams and mark.
6. Lay the rear beam across the hulls at the rear channels and measure the precise distance from the beam to the lines drawn parallel to the sheer line on the inboard hullsides. Then on the outboard hullsides draw lines parallel to the sheer the same distance below the beam as on

the other side.

7. On all four hullsides at each side of the beam, draw a perpendicular line from the sheer to the lines below the beam.
8. Repeat steps 6 and 7 for the mainbeam. Since the mainbeam is pre-curved, the horizontal lines on the outboard side should be 2mm lower than the inboard side.
9. Make templates to the shape of the main and rear beams.
10. Center each template between the vertical lines at the beam channels and mark the shape to be cut out.
11. Use a saber saw and cut out each channel on both sides of the hull close to the line. Use a file and straight edge across the hulls to get the shape right. Seat the beams until they fit to both sides of each hull.
12. Re-check the hull setup.

Part 2

1. Fit the 4mm ply bottoms for all the beam channels as close below the cutouts for the beams as you can. At the main beam, be sure to allow space for the dolphin striker and its fasteners.
2. Epoxy coat all pieces.
3. Allow to cure.
4. Install channel bottoms with a fillet mixture and staple in place to the bulkheads. Fillet to the deck beams.

K. Install beams in channels

Part 1

Install beam bolts and/or studs Part 2

Reinforce bolt retainers Part 3

Install jib stop plate retainers Part 4

Part 1

1. Coat the bottom and sides of both beams with a release agent where the beam will enter the hull. A paste wax with several coats and wiped smooth works well. Be sure to fill the grooves where the dolphin striker attaches to the beam.
2. Fill the rear beam channels with a soft microsphere mixture. Use plenty so that it will be squeezed out.
3. Lay the rear beam across the channels and push down gently until the beam is seated completely. Wipe away excess microspheres as the beam is seated. Innertube clamps laid diagonally across the beams and around the hull are tightened to insure complete seating.
4. Repeat the same process for the main beam.
5. Re-check alignment again before the microsphere mixture cures.
6. Allow to cure. NOTE: Regardless of your choice of beams, the previous steps will be the same. Depending on your choice and method of attachment, the next steps may need to be altered. Permanent studs are recommended for both beams at each point, however a beam strap is required for the inboard sides of the main beam due to the curvature of the beam. Permanent studs are stronger, lighter and easier to install than removable bolts.

Part 2

1. After the microsphere mixture has cured and after the clamping straps are removed, the bolt

or stud holes should be drilled. Use a long 3/8" drill bit and drill down through the beams into the hull. Remove end caps and look inside the beams as you are drilling to avoid enlarging the holes in the beams. Drill all holes for both beams and be sure to drill all the way through the beam chocks for the removable bolts. For the permanent studs drill 65mm into the beam chock on the inboard side and 50mm on the outboard side. Fit the studs in place and cut to length.

2. Remove the beams. If the beams are stuck in the microsphere mixture, heat the beams on the inside with a torch and they will come off. Use moderate heat and allow time for the beam to cool and contract. Repeat several times if necessary.
3. Fit the beam bolt retainer plates for the bolts. You may need to chisel or drill to provide sufficient space for the retainer plates under the beam chocks.
4. Enlarge the bolt holes into the hulls slightly with the 3/8" drill for those bolt holes that will have removable bolts. Use a pipe cleaner and epoxy coat those bolt hole edges to seal the wood.
5. For the permanent studs, fill the 65mm hole with epoxy and allow to sit for 15 minutes. Push the studs in slowly and wipe away all excess epoxy.
6. Allow to cure.
7. Re-install the beams again unless you have used permanent studs. Install the bolts with the retainer plates. For the removable bolts, epoxy coat the retainer plates (except near the tapped hole) and tighten firmly in place.
8. Prepare a fillet mixture and fillet around the retainer plates.
9. Allow to cure.

Part 3 (Not necessary if permanent studs are used)

1. Remove beams and set aside
2. Turn the hulls deck down.
3. Prepare a fillet mixture and fillet around the retainer plates again to increase the bonding surface, be sure to avoid the tapped holes.
4. Allow to cure.

Part 4

1. Install 3/4"x1/2" strips of spruce under the inboard gunwales as reinforcement for the cross-hull jib strop plate. The reinforcement strips should be from 36" to 50" aft of the rear of the main beam.

L Sand deck structure Part 1

Install stringers

Prepare decks Part 2

Install decks

Part 1

1. Use a long sanding block and sand the gunwales and deck beams. Use the deck template to insure the fit.
2. Install the deck stringers using epoxy in the notch outs. Use a single staple, if necessary, to hold the stringers in place. A single small fillet where the stringers join the deck beams is sufficient.
3. Allow to cure.

4. Sand the deck structure, coat with epoxy, and sand lightly to remove bumps.

Part 2

1. Fit each deck, mark each piece Port and Starboard and set aside. Hold the ply tight to the hull and mark the outline on the underside of the ply. Drill out holes and file smooth for the shroud chainplates and the permanent studs. Cut out the ply pieces 3mm oversize.
2. Prepare three pieces of 15mm by 20mm wood to the length of the front deck to be used for clamping sticks at the deck center and the gunwales.
3. Make chalk marks on the outside of each hull at each deck beam location. These marks will be used to locate the clamping straps.
4. Epoxy coat one deck piece on the inner side and set aside.
5. Fillet the deck beams, gunwales, and stringers with a medium fillet mixture.
6. Re-coat the deck piece on the inner surface with epoxy and place on top of the deck structure.
7. Set the clamping sticks on the deck and pull the deck down tight with 50mm innertube strips at each deck beam.
8. Wipe off all excess fillets and allow to cure. Repeat for each deck piece.

M. Finish deck edges and channels

Prepare hull surface for glassing

1. Use a plane or router to remove the deck edges. Bevel the edges to a well rounded shape. On the outboard hull sides from the main beam to the transom increase the radius of the bevel to 10mm for easier trapezeing. Sand the edges smooth.
2. Remove the deck edges in the channels to continue the beam shape. A small surfboard plane replacement blade held by hand works well.
3. Sand the entire hull using 160 grit paper on a large sanding block. Use as necessary to be sure that the hull surface is completely fair and the long sanding block helps. A 75mm by 300mm block is sufficient.
4. Do not be concerned if you have any small nicks or gouges as they will be filled later. NOTE: The choices available for finishing include painting, natural wood finish, or a combination of the two. The glassing and epoxying steps are the same in any case.

N. Fiberglass and flo-coat hullside

Prepare for finishing

Fiberglassing the exterior hulls surfaces has two advantages. First and foremost, it increases the abrasion resistance substantially. It has some additional benefit in increased flex strength. There are two general techniques: you can glass off the bare wood or epoxy coat the surface after it is cured, lightly sand and fill where necessary before glassing. The second technique appears to be the best and it is described here.

1. Coat the hulls lightly with a single coat of epoxy to seal the wood.
2. Allow to cure and sand lightly to remove bumps. Fill any nicks with epoxy, allow to cure, and file smooth.
3. Lay the glass cloth previously prepared on the hullside and tape in several places so it will not slide off.
4. Use a spreader to apply the epoxy over the cloth. Make small batches of epoxy and start at

the bow by pouring small amounts of epoxy on the hull and spreading it out thinly. The idea is to squeeze the cloth tightly to the hull using a minimum amount of epoxy. The grain of the cloth will show but the color will be of the wood.

5. Wipe off any drips that go over the edges to avoid having to sand them later.
6. Don't worry about the cloth overlap at the deck and keel at this time.
7. Don't be concerned if you can still see the weave of the cloth because when the surface is coated again with epoxy, the weave will disappear. If you can see any white spots on the surface, apply a little additional epoxy and smooth in, these will be air bubbles under the cloth. You will need a well lighted work area to be able to see these spots.
8. Allow the surface to semi-cure and then take a razor blade and trim the cloth at the sides of the hull- This should be done when the cloth at the edges has become fairly stiff.
9. Allow to cure and repeat for all hull surfaces.
10. Look the surfaces over and sand or file off any bumps. If white spots did occur, cut the cloth out carefully and fill with epoxy. Allow to cure and sand and file the spots smooth. File and sand the edges of the surface only.
11. Glass the deck before cutting out the centerboard trunk opening. Allow to cure.
12. Carefully drill pilot holes and locate the ends of the trunk slot and widen to the sides. Draw lines parallel to the inside of the slot and cut out with a saber saw. Be careful not to scratch the walls inside the trunk. Sand and file the edges smooth and bevel slightly. The router can be helpful here.
13. Flo-coat each surface using a roller and spread the epoxy evenly. The first coat will close the pores of the cloth about 60%. Allow the first coat to cure and apply a good second coat to complete the process. Allow to cure.
14. Wet sand the hulls smooth with 80 and 180 grit wet paper. Use a long flat sanding block with the 80 grit paper. You can use the sanding block or a high-speed finishing sander with the 180 grit paper. Be sure to use plenty of water as you go along to keep the paper from loading up and then scratching the surface.
15. If you use a 4oz flat weave cloth and follow the procedures above, you will have added about 7# of weight to the hull. If you choose to eliminate the glass cloth and replace it with additional coats of epoxy, the weight added would be about 5#. Glass cloth is recommended.

O. Install gasket material Part 1

Install deck ports Part 2

Part 1

1. For the centerboard trunk gasket, draw lines 5/8" from the edges of the trunk all around. Notch out carefully with a router set to the depth of the gasket material to be used.
2. Bevel the edges at the trunk slot to leave a gap so that the gasket material can deflect downwards when the board is down.
3. Install the gaskets with a good quality waterproof contact cement.
4. After the adhesive cures, draw a line down the center of the gasket and cut with a razor blade carefully. The edges should butt together but not overlap at the center of the trunk.
5. Fair in the gasket material and sand smooth

Part 2

1. Mask over the area to be cut out to prevent scratching to the surface.

2. Draw the circle required to the size of the inner flange of the port.
3. Drill a pilot hole inside the circle and cut out with a saber saw.
4. Drill slightly undersize screw holes.
5. Sand 6mm around the exterior of the cut out to make a good bonding surface.
6. Apply a medium microsphere fillet, coat the inside surface of each screw hole, and screw down the inspection port with small stainless screws. Do not draw the lateral edges down tightly as it will be easier to screw the port in if it is not curved. Wipe away excess microspheres.
7. An option here is to use only one screw fore and aft, the microspheres will come up into the screw holes in the port and seal perfectly. NOTE: the hulls are now ready for the finishing.

P Finish hull surface

Part 1

Install fittings Part 2

Measure for trampoline Part 3

Part 1

1. If you choose to have any part of the hull surfaces painted, mask off the rest of the hull with masking tape and newspaper. For large areas to be painted use a spray gun. For stripes, small areas, or the boat name, use a small can of spray paint. For waterline on the hulls, use the plans.
2. Allow to dry and wet sand the painted surfaces with 400 grit wet paper.
3. Natural wood surfaces will need to be coated with clear polyurethane having an ultra-violet sun screen. Coat all painted surfaces also. The easiest way to spray hulls is to suspend them by the beam studs and spray the entire hull at one time. Mask off the chainplates, channels, studs, ports, and centerboard gasket. See paint recommendations previously mentioned.
4. Allow to dry and wet sand with 400 grit paper.

Part 2

1. Assemble the hulls with the beams.
2. Install the trampoline tracks centered between the beams. Use 20mm stainless wood screws to hold the tracks in place. Start at one end of the trampoline track, drill a slightly undersize hole, epoxy coat the hole with a nail and install the screw. Drill the next hole and repeat the process. The trampoline track will be bent slightly as you go along to accommodate the curve of the hull. Use Philips-head screws, they are easier to install and remove later for re-finishing. If your trampoline track has a jib stop slider, use 30mm screws in the area where the stop will meet the hull.
3. Install the rudder gudgeons and pintles next. Use a rudder measuring template.
 - A. Assemble the hulls and beams on a trailer or in cradles and level the rear beam.
 - B. The pintles and gudgeons should be as far apart vertically as possible to spread the load.
 - C. Align carefully in the vertical plane at the center of the transom using a plumb line.
 - D. Drill and bolt trough the transom using large washers inside. Lock nuts are unnecessary if the nuts are epoxied onto the bolts. Tighten firmly.
 - E. With the rudders in place, mark the screw holes for the plastic rudder retainers. Remove the rudders and drill the screw holes for the rudder retainers.
4. To locate the tiller connector holes, set the rudders vertical with the hulls and align by measuring the distance at the rudder leading edges and at the trailing edge of the rudders at

the keel. When the measurements are equal, wedge in place and drill the necessary hole in the tiller connector.

5. Install the stick-on non-skid tape on the outboard gunwales from the main beam to the transom. Wrap around the gunwale with most of the tape on the hullsides. The recommended locations is from 2" in front of the main beam to the transom.

Part 3

1. Measure for the trampoline by taking measurements across the hulls at every 12" starting at the main beam. Measure to the edges of the trampoline track. Measure from the aft edge of the main beam to the rear beam. Make a drawing of these dimensions to be used for the trampoline supplier.

NOTE: The hulls are now complete and the boat is now ready to be rigged.

PROCEDURE FOR INSTALLING TRAMPOLINE LACING EYES

1. Be sure to install 1/2"X3/4"X11/2" blocks under the gunware at each location to be drilled.
2. Use a 9/16" wood drill bit and mark for 5/8" total depth of a hole. Bright colored tape works well as a marker.
3. Mark the inboard sides of each hull starting at the rear of the main beam. The first mark is 6" aft of the beam, and the spacing between marks is 6" for the remaining marks. The top of the hole is to be drilled should intersect where the deck and hullside meet.
4. Drill each hole carefully keeping the drill vertical to hullside. If the point of the drill goes through the wood, fill the hole with thickened microspheres and allow to cure.
5. Adjust the hulls so that the hullsides at the deck area are level and fill each hole with a 206 mixture about 2/3rds full.
6. Push shackles into hole and use a 3" piece of plastic soda straw to align the shackles parallel with the deck edge and to hold the shackles up high enough to allow for the lacing line.
7. Allow to cure.
8. Remove soda straws, and fill holes to the top using a syringe. If you align the hulls so that the shackles are horizontal, the syringe filling can be done to the top without overflow. If you are careful no sanding will be required.

NOTE: Trampoline lacing eyes are installed after all finish sanding is done, just before varnish or paint.

Recommendations – Hull measurement

Class rule

- | | | |
|------|----------------------------|--------|
| 8.i. | Deck centerline separation | 2625mm |
| 9.f. | Beams set into hull | 28mm |

9.i.	Rear edge of main beam aft of bow	3100mm
9.j	Front edge of rear beam aft of bow	5335mm
11.d.	Leading edge of centerboard aft of bow template	2480mm
16.a.	Shroud chainplate aft of aft edge of main beam	715mm
16.c.	Forestay chainplate forward of aft edge of main beam	1985mm
16.d.	Bridle height	840mm

Rigging the boat

The best way to decide how to rig your boat is to attend several regattas, look carefully at the faster boats, and discuss what you see with the Tornado sailors present. Ideas about rigging change and are dependent upon the way helmsman and crew divide the responsibilities while sailing.

Another source of information is a good sailmaker. If you buy sails from a sailmaker you can usually expect him to provide advice.

The following notes are general in nature and will help you get started.

Trampoline

With the hulls set up, slide the tramp on the boat from the front. A one-piece tramp of black polypropylene is good. If the material is sewn at a 45 degree angle to the hullsides it will stretch tightly from the rear. Be sure to have the following:

1. One or two pockets at the front for halyard tails.
2. Hiking straps sewn on at the front and tied at the rear beam.
3. Lashings under the tramp at the main beam for anchor and paddle.

Jib strop

There are several ways to attach the jib blocks to the boat.

1. Jib strop across the hulls. This strop may be moved fore/aft on the jib strop plate or on trampoline track slides and the blocks may be moved inboard/outboard several ways.
2. A pair of fore/aft jib strops attached between the beams.
3. Blocks mounted on the hulls used in conjunction with a barber in-haul on the boom.

The first alternative is the easiest and most flexible. Recommend 3mm (1x19) wire covered with 1/4" plastic tubing.

Jib systems

The jib blocks are usually ratchet blocks with beackets and adjustable cleats and the jib sheet is usually a continuous 3/8" sheet line with 2-part purchase. A barber outhaul can be fitted to the ends of the main beam to pull both lines outboard for off wind sailing.

Mast standing rigging

Shrouds

Recommend 3mm (1x19) wire with a nicopress and thimble fitting at the top and a turnbuckle or halfturnbuckle at the hull attachment point.

Forestay

Recommend 3mm (1x19) wire with a nicopress and thimble fitting at the top and a turnbuckle at the bridle attachment point.

Forestay bridle

Recommend 3mm (1x19) wire with fork terminals for hull attachment and one fork-one eye terminal for attachment to the forestay turnbuckle.

Diamonds

Recommend 3mm (1x19) wire with fork terminals at the top and shroud adjusters at the bottom. Don't forget to install the plastic sail protectors when preparing the wire.

Mast-running rigging

Main halyard

Recommend 1/4" line (62') with halyard ring for the top of the mast.

Jib halyard

Recommend 3mm (7x7) wire. Swage a shackle with a retainer pin to one end, and a

thimble to the other end. A halyard tail of 3/16" or 1/8" line is sufficient. The halyard wire should be attached to a 3 or 4 part purchase device to allow adjustment of the jib luff.

Trapeze wires

Recommend 2mm (1x19) wire with thimbles at the top. At the bottom, a trapeze handle and a block for 1/4" line. Use a short line led trough the block and attach the trapeze ring to one end and tie a knot at the other end. At the knotted end attach shock cord (3/16") and lead trough mainbeam to the other trapeze wire.

Boom

Mast angle control

There are two general ways to limit the rotation of the mast. The control line from the mast rotator can be attached to the boom or from the base of the mast to a pair of lines under the trampoline that lead to the two hulls.

The recommended method is to lead the mast rotator control line to a clam cleat mounted on the top of the boom.

Main downhaul (luff tension)

A minimum of a 6 part downhaul is required to be able to adjust the main easily. There are numerous ways to arrange the purchase including:

1. A pair of triple blocks
2. A "magick box", mounted on or in the mast
3. A drum winch mounted on the mast

The easiest method is to use a pair of small triple blocks with the control line leading to a clam cleat mounted on the top of the boom.

Clew outhaul

The clew should be attached to a roller traveler mounted on top, or inside, the boom. The amount of travel needed is 8-10". A minimum of a 4 part purchase is needed to outhaul the sail. The inhauls is controlled by heavy shock cord (3/8").

Mainsheet system

A 7 or 8 part purchase system is recommended. Roller bearing blocks are a real asset. A ratchet block as the last block with a cam cleat mounted on it can be used in steady air. The sheet line (3/8") can be a continuous line and serve as the sheet for the 2 part traveler control line also. Attach the blocks well aft on the boom to rotate the mast.

Centerboard control

The centerboards can be controlled with friction tape or with control lines and cleats. Direct control with friction tape works well with a good crew and is very clean. The method should not be used if you sail in water having a lot of weeds, control lines are better in this case.

PHOTOS

1. An excellent scarf joint glued with WEST epoxy. They should be kept at least 4 feet from the transom	2. The hullsides drawn, cut to shape, and matched to the other hullside. Ready now for wiring up.
3. Hullsides wired together, gunwales wedged apart to get the correct keel angles, and the inside keel glassed.	4. A deck jig on the right built from the plans. Rough cradles on the left to support the hullsides until the inside keel is glassed.
5. Copper wires have been cut off and the keel sanded. Masking tape being installed before outside keel glass is put on.	6. Hull being wetted down in preparation for folding into the deck jig. The other hull ready for this step also.
7. Hull inside the deck jig and held in place with three strap clamps. The deck jig is supported by parallel sawhorses. Note the support stick holding the transom shape while the wood dries.	8. Deck jig turned over and supported by the sawhorses. Ready now to fit transom.
9. Transom fitted and epoxied into place. A fillet on the inside completes the glueing process. Fasteners are unnecessary. Note how the clamps force the transom down to the hullsides.	10. Main bulkhead in place. A loose fit is desirable since 10oz glass cloth will be between the bulkhead and the hullside.
11. Main bulkhead epoxied in place and held there by the beam chocks. Foam bowspacer installed.	12. Hullsides completely glassed and coated. Siamese cat observing it all.
13. All bulkheads completely filleted and all deck beams installed that can be at this stage. Hull may be removed from the deck jig at this point.	14. Centerboard trunk sides graphite epoxied on the inner surfaces and stringers epoxied in preparation for making the trunks.
15. The finished trunk with picot slot.	16. Centerboard trunk epoxied in place and clamped.

17. Keel area of trunk cut out and filled and sanded smooth.	18. Forestay tang epoxied in place and clamped.
19. Shroud chainplate installed. Note large glue surface. Chainplate is set into the triple support piece.	20. Both hulls constructed, bows ready to be glassed. A nice touch here is to plane off the bow past the wire holes, install a solid wood bow stem, and plane to shape.
21. Transom view of both hulls.	22. Rear deck being installed with clamp straps and deck jig.
23. Trunk installed with remaining deck beams and stringer. Ready for fitting of beams.	24. Rear beam installed in channel with microsphere fillet. Clamped in place and curing. Alignment perfect.
25. Hulls aligned and beams installed. The next steps are to install studs and then the middle deck.	26. Hull has been sanded and glass being installed. Edges are trimmed when epoxy is semi-cured.
27. Hulls varnished ready for final wet sanding and buffing.	28. View showing mylar slot gaskets, laced trampoline.
29. A beautiful custom ply Tornado at the Olympic Trials.	30. A Gougeon Tornado at the Trials. Note the very clean rig, laced tramp and jib stop.
31. Two Tornados ready for travel.	32. The whole point of amateur building. <u>Super</u> boats racing!