



This project was created by Tony Bergerson (ASM with Troop 520 in Cedar Hill, TX and an engineer at Bell Helicopter) in 2009 to help scouts in his troop earn the Composite Materials merit badge. These instructions provide guidance to someone familiar working with composite materials to lead a group of scouts in constructing their own composite hiking staff.

Feel free to share this with other scout groups in order to promote the Composite Materials merit badge.

## Materials needed

### Phase one: Composite tube

#### A. Shop supplies

1. Well ventilated work area
2. Hack saw for cutting PVC to length
3. File or sand paper to smooth ends of cut PVC
4. Rubber gloves – disposable type
5. Safety glasses
6. Plastic sheet (6 x 2 foot piece for each Scout)
7. Digital scale for weighing resin mixture (or pre-measured resin kit)
8. Adhesive tape
9. Mixing cups
10. Mixing sticks
11. Squeegees for spreading resin onto fabric
12. Heat gun for shrink tape

#### B. Project supplies

1. PVC Tube 60" long,  $\frac{3}{4}$ " class 200 (actual outside diameter is 1")
2. Composite Reinforcement (fiberglass, graphite, Kevlar, hybrid)
  - a) Woven fabric – 50" W x 10" L for 3K plain or twill weave (provides 3 layers wrapped) --or---
  - b) Braided Tube – 100" L x 1.5" dia for 6K braid (cut in half to make 2 layers)
3. Resin ~ 90g low viscosity RT cure epoxy (simple rule of thumb – resin required should equal the weight of the dry fabric for graphite and aramid materials). Loctite 0151 in a 3.3 oz kit and West System Epoxy are two acceptable choices.
4. 10 feet of 2 ½ inch wide shrink tape (release coated, Dunstone is one mfg)

# Materials needed (continued)

## Phase two: Finishing kit

### A. Shop supplies

1. Safety glasses
2. Hack saw for trimming PVC tube ends
3. File or sand paper for smoothing cut ends of PVC
4. Drill with 1/8" bit for lanyard holes
5. Black spray paint
6. PVC cement
7. Quick set epoxy glue (or equivalent)

### B. Project supplies

1. 1" copper end fitting
2. PVC threaded adapter
3. PVC threaded plug
4. Cushioned grip (tennis racquet grip, bat grip, bicycle grip, para-chord, etc.)
5. 20" lanyard (1/8" dia rope, leather shoe lace, etc.)

# Phase one: Fabricate composite tube

1. Cut PVC to length
  - PVC is available in 10 foot lengths from local hardware stores. Cut section in half to provide two 5-foot lengths
  - De-burr the cut ends of the PVC to remove any particles and rough /sharp edges
  - If dirt is visible, lightly sand with scotch brite or medium/light sandpaper.
  - Always wipe surface with safety solvent (alcohol recommended) as the last prep step.
2. Cut composite fabric to size
  - A 50" x 10" section of cloth (3K weave) provides 3 layers to the 1" OD PVC tube
  - If using braided sleeves, use 2 layers of a 50" long 6K braid for best thickness to weight.
3. Prep work space
  - Use the plastic sheet to cover the work space. You will use this to squeegee the resin into the fabric and to catch drips as the material is wrapped onto the tube.



4. Calculate resin required (and mix ratios)
  - Use 15g resin per square foot of 3k weave material
  - Another good target is to use the weight of the fabric (for graphite or aramid) as the required resin weight.
  - Always best to err on the high side because you can squeeze out the excess resin before wrapping the tube
  - Be sure of you mix ratio math before proceeding. For example, if a resin system requires 100 parts A and 40 parts B, the following equation gives the proper amounts for a 90 gram batch:

$$100 \text{ A} + 40 \text{ B} = 140 \text{ Mixture} \quad \frac{90 \text{ grams required}}{140 \text{ gram mixture}} = 0.64 \text{ mix factor}$$

$$\text{Part A} = 100 \times 0.64 = 64\text{g} \quad \text{Part B} = 40 \times 0.64 = 26\text{g} \quad \text{Total is } 64\text{g} + 26\text{g} = 90\text{g}$$

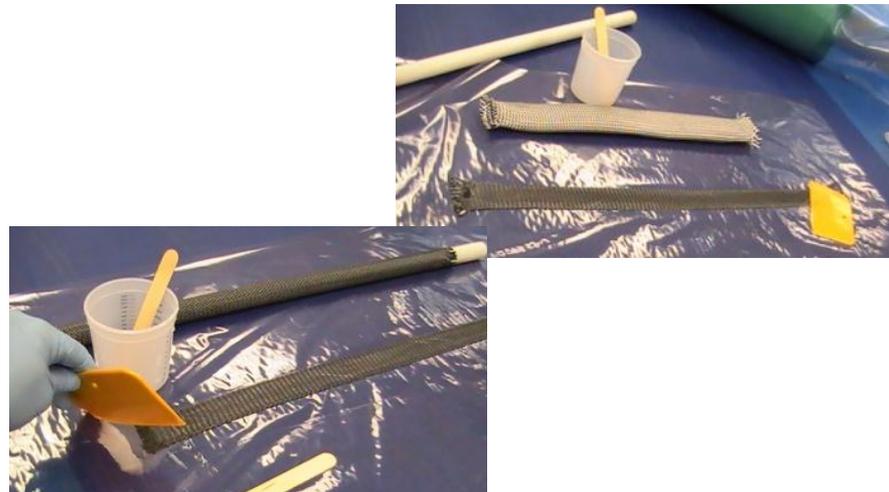
## Phase one: Fabricate composite tube

### 5. Mix resin

- Carefully measure the amount of resin and hardener required per the manufacturers instructions. Mix thoroughly (~2 minutes) making sure to scrape the edges of the cup periodically.

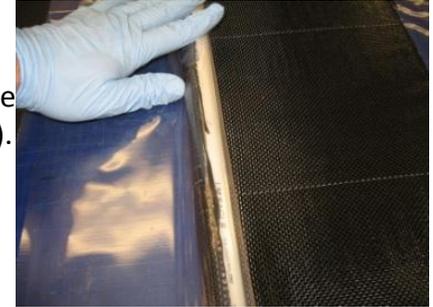
### 6. Apply resin to the fabric

- If using fabric, pour the entire amount of resin onto the fabric surface. Pour the resin over as much area as you can to make it easier to spread with the squeegee.
- If using braided sleeves, divide the resin equally between the sleeves. Squeeze out from the first ply can be used to saturate the second one if needed.
- Use a flexible squeegee to spread the resin around the fabric and press firmly to work it down into the fibers. Continue working the resin into the material until it is 100% saturated, including all the edges.
- For braided sleeves, flip it over and be sure both sides have been saturated (this step not required for flat fabric).
- Once the material is fully saturated, use the squeegee to pull as much resin as possible out of the fabric and into a puddle on the plastic sheet. Excess resin in the fabric adds weight and may cause wrinkles during the heat shrink application. Once the fabric is saturated, it is impossible to squeegee too much resin back out of the fibers. Carefully examine the composite to be sure no dry spots exist.



## Phase one: Fabricate composite tube

7. Roll/slide fabric onto PVC tube (caution: this is where the project gets very sticky)
  - If using fabric
    - Align the material back into a rectangular shape. It tends to distort while working in the resin.
    - Remove any loose fibers from the edges
    - Position the PVC tube centered along the fabric edge and roll the fabric onto the tube. To get the first wrap started it helps to roll the plastic and fabric together onto the tube (since it is stuck together). Then peel the plastic back and continue rolling onto the fabric.
    - Roll slowly while trying to eliminate any sags, wrinkles or loose areas in the fabric.
  - If using braided sleeves
    - Shorten the sleeve to expand the diameter (Chinese finger cuff effect).
    - Slide the first layer completely onto the PVC tube. Working from the center, slide your hands along the sleeve to stretch it out and shrink it down onto the tube. Wrap your finger and thumb around the material (always starting from the center) and slide them along to each end to remove excess resin.
    - Add the second sleeve layer in the same fashion (shorten first, then slide completely over the first layer).
    - Repeat the process of working the material from the center to end to pull it down tight to the first layer. The more resin you squeeze out here, the lighter your staff will be.
8. Smooth the fabric surface and squeegee off excess resin with hands. It may help to add some twisting motion while working the material along the tube in order to get a good tight fit.
9. Cut/remove stray fibers if needed
10. Wipe the resin residue from the PVC ends not covered with fabric



Note: at this point you may wish to change gloves because you are now done with the messy part.

## Phase one: Fabricate composite tube

### 11. Wrap tube with shrink tape material

- This is an optional but highly recommended step. Once the fabric material has been smoothed out onto the PVC tube it can be left to cure in a safe clean location. The surface of the cured part without shrink tape will have a mat finish but will still be structurally sound for this application.
- Adding a shrink wrap helps in 3 ways
  1. Physical benefit: compresses the fabric onto the PVC which flattens any remaining wrinkles and squeezes out additional excess resin
  2. Visual benefit: produces a gloss finish on the part which gives it a very professional look.
  3. Handling benefit: protects the surface while it cures. Allows the part to be safely transported or stored while awaiting the typical 24-72 hr cure time required.
- Spiral wrap the shrink tape along the tube. Use generous overlaps to provide a smoother finished part.

### 12. Apply heat to the shrink tape. Use a heat gun (industrial strength blow dryer) to shrink the tape. Begin near the center of the part and work toward each end. This helps prevent wrinkles and allows excess resin to move out of the part. Some resin will squeeze out between the wraps so have a piece of plastic under your work space to catch the drips. Use caution not to over heat the assembly. Too much heat will soften the PVC tube and give you a bowed part. Be sure to check and correct the straightness as soon as you finish applying heat.



### 13. Wait for the appropriate cure time. Store the part in a manner which keeps it straight. Don't be tempted to unwrap it early. Applying some heat (<math><140^\circ</math>) to the part usually helps the part cure better (faster and stronger). During summer months the inside of a car often provides a convenient oven cure.

### 14. Unwrap tube and begin hardware attachment

## Phase two: Finishing hardware

1. Choose which end will be the bottom. This should be the “better looking” end since it will not be covered with a grip.
2. For the bottom, use a hack saw to cut the PVC tube flush with the composite material. If there are a few strands of fiber sticking out the hack saw will easily cut these as well.



3. For the top, mark the cut line on the PVC ¼ inch above the composite material and cut with a hack saw

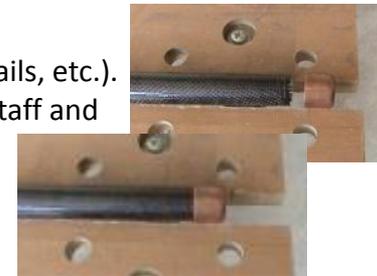


4. Smooth both ends of the PVC using a file or sand paper.



5. Check for proper fit of the copper bottom fitting. Fit should be snug. If too tight use sand paper to thin out the bottom end of the staff.

6. Glue the copper fitting on with a thick water proof glue (epoxy, liquid nails, etc.). Apply adhesive to the inside edges of the copper tip. Slide it onto the staff and seat it firmly by tapping the staff on the ground a few times. Wipe off any adhesive that may squeeze out. Let the epoxy cure for the time stated by the instructions before using it. You can continue building the hiking staff while it cures.



7. Check for proper fit of the PVC coupling on the top. Resin squeeze out may prevent it from sliding down to touch the composite material. Use a file or sand paper to remove any resin buildup. If a stray fiber is extending into this area, press down firmly with a box cutter or sharp knife to shear it off.



8. Use PVC cement to bond the PVC coupling to the top.



## Phase two: Finishing hardware.

9. Drill holes for lanyard in the threaded cap.



10. Optional: spray paint PVC fitting and threaded cap black to match general color of the hiking staff.

11. Install lanyard

12. Wrap your grip

13. Customize your hiking staff even more.

- Use para-chord to make a rope grip
- Add a small compass to the end plug
- Store useful items inside your staff
  - First aid supplies
  - Small flashlight
  - Light stick
  - ????

14. Take a hike!

