



DEPARTMENT OF RADIOLOGY AND IMAGING SCIENCES

Skin Cooling System

Cooling Pad Manufacturing Tutorial

Revision A

February 2021

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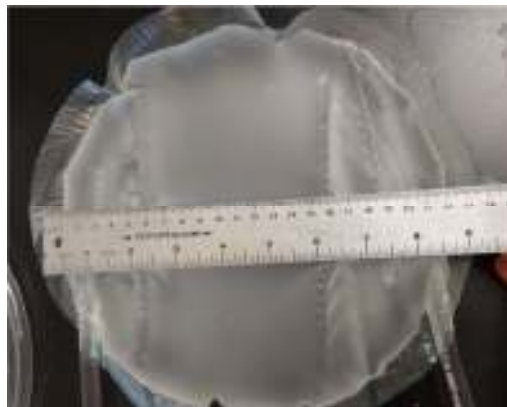
Section 1 – Introduction

This tutorial describes the manufacturing process for Skin Cooling Pads to accompany the Skin Cooling System developed by the University of Utah. This tutorial assumes that a functioning Skin Cooling System (Cart, Control Box, etc.) is available for pressure-testing pads once assembly of a pad is complete.



A few items of note:

- The templates necessary for this tutorial are available for download (link provided in Section 2). The pad design of the template is presently being clinically evaluated. The current design is for a 22 cm diameter inflated pad with four internal baffles (see photo below). This design maintains convective water flow within the pad and an open (un-baffled) center for ultrasound transmission.



(Due to camera parallax, '0' point of ruler does not appear aligned with inflated pad diameter in photo)

- Considerable time is required to develop a 'feel' for the pressure and speed required for welding seams. It is recommended that scrap membrane be used for practice prior to attempting a working pad. The heat shield tool described Section 3 of this tutorial is required for making practice welds. A properly welded seam passes the 'pull-apart test:' when the two membrane pieces are pulled in opposite directions very hard, the welded seam pulls apart very little or not at all. No quantitative studies have been performed to analyze welded seam strength.
- The approximate cost of the materials listed in the *Required Tools and Supplies* section of this tutorial is **\$750**.

Section 2 – Required Tools and Supplies

2.1 Membrane material

Thermoplastic Polyurethane TPU-780000650M Polyether
.15mm thickness

Plastic Film Corporation (supplier)

<https://www.plasticfilmcorporation.com/polyurethane-film.html>



2.2 Template paper

11" x 17" paper
Staples.com
Item #756978



2.3 Marking pen

Sharpie ultra-fine point pen
Staples.com
Item #282566



2.4 Hobby knife

Xacto (or similar brand)
Staples.com
Item #137331



2.5 Steel rule

English and Metric ruler with non-slip cork backing
Staples.com
Item #2772901



2.6 Cutting mat

12" x 18" (30.5 cm x 45.7 cm)
Staples.com
Item #609016



2.7 Scissors

Fabric- or fine-cutting scissors
Staples.com
Item #571830



2.8 Roller welder kit

Constant heat roller sealer
(modified with additional lead weights)

US Plastic Corp.
<https://www.usplastic.com/catalog/item.aspx?itemid=35723&clickid=search>



2.9 Kapton heat-resistant tape

Tekline Kapton/Polyimide 2" (5 cm) wide tape

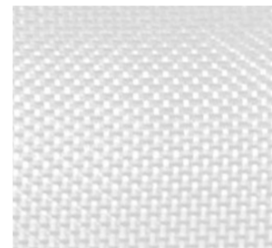
CMLSupply.com
<https://www.cmlsupply.com/tekline-premium-kapton-tape-2-x-36yds-1mil-polyimide/>



2.10 Fiberglass mesh

1.4oz fiberglass mesh

ACPComposites.com
<https://store.acpcomposites.com/1.4-oz.-fiberglass-plain-weave-fabric-style-108-1080?quantity=1&length=12&width=18>



2.11 Laboratory tubing

1/4" ID, 3/8" OD clear vinyl tubing
(Tygon, Saint-Gobain, or similar brand)
McMaster-Carr.com
Item #6516T21



2.12 Vinyl adhesive

Loctite vinyl, fabric, & plastic adhesive

Ace Hardware.com
Item #1490796



2.13 Small spatula

Double-ended with one tapered end
Zoro.com
Item #G6394158



2.14 Plastic hemostats

MRlequip.com
Item #TW-5011 (10 pack)



2.15 Weights

Miscellaneous small, heavy objects



Section 3 – Heat Shield

Note: The following instructions describe how to make a heat shield tool to prevent direct exposure of heat to the membrane during welding. Only one heat shield is necessary, and will last for welding many pads over time.

- a. Mark and cut two 2.5 cm x 20 cm strips of fiberglass mesh

- b. Pull Kapton tape from the roll and cut to approximately 30 cm long.



- c. Place the metal ruler on a flat surface. Place the Kapton tape sticky-face-up over the ruler so that the tape overlaps ruler edge by 1 cm.

- d. Tuck the tape ends under by approximately 2 cm on each end, so that the tape strip is held tightly to the ruler



- e. Carefully align the cut edge of a fiberglass strip to the edge of the ruler, as seen through the transparent tape. Center the fiberglass end-to-end on the tape, and press firmly in place.

- f. Remove the tape from the ruler and set it aside sticky-face-up.

- g. Repeat steps b – e with the second fiberglass strip and additional Kapton tape.



- h. While the second fiberglass/tape assembly is still attached to the ruler, carefully place the first assembly directly on top (sticky faces together) with the fiberglass edges directly aligned. The fiberglass is now captured between the two tape layers.



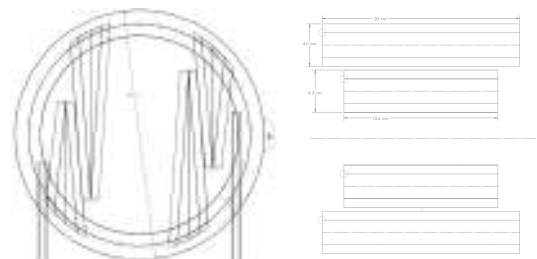
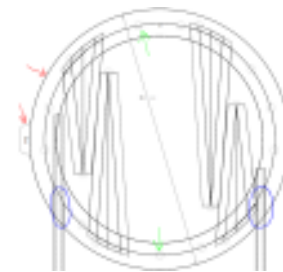
- i. Remove the assembly from the metal ruler and cut away any tape edges that have exposed adhesive, so that the tape edges are approximately 1 cm from the fiberglass edges



Section 4 – Templates, Marking & Cutting

4.1 Marking

- Obtain Skin Cooling Pad templates from:
https://github.com/fuslab-uofu/SkinCoolingDevice/FinalProduct/AssemblyFiles_Pad/
- Print templates on 11"x17" paper. Lay out templates on a flat surface
- Cut 12" (30.5 cm) strip of membrane from supply roll, and place over 'Top' template (large circle with tab marked 'T')
- Trace outer edge of template onto membrane, including the tab and letter 'T' label (red arrows)
- Trace tubing center lines onto membrane (indicated with blue circles)
- Place dot at the center of each small circle (green arrows show two examples, please mark all circles)
- Repeat steps *b-f* above for 'Bottom' template (large circle with tab marked 'B')
- Mark the outer edges of the 'Baffle' pieces, with a dot at the center of each small circle



4.2 Cutting

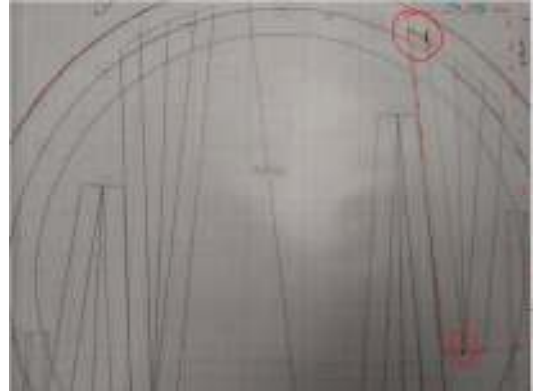
Using scissors, carefully cut out 'Top' and 'Bottom' membrane pieces following the marked outlines. 'Baffles' may be cut with scissors or with steel rule and hobby knife.



Section 5 – Welding

6.1 Bottom Baffle Weld #1

- a. Heat the roller welder to 190 degrees Celsius (turn the heat adjustment knob to half-way)
- b. Place the cut 'B' membrane over the 'Bottom' template
- c. Place the small cut 'Baffle' on top of the 'B' membrane at the position closest to the 'B' tab (red dotted outline of Baffle shown). Align the marked dot on the 'Baffle' with the corresponding dot on the 'Top' membrane (lower red circle)
- d. Mark the Baffle end as shown in the upper red circle



- e. Trim the Baffle as shown



- f. Place 'B' membrane on silicone welding mat. Return the trimmed Baffle to the corresponding alignment dots on 'B' membrane in preparation for welding



- g. Place fiberglass heat shield on Baffle and 'B' membrane. Align edge of captured fiberglass with alignment dots (red arrows). The captured fiberglass should cover the portion of the Baffle to be welded (photo shows weld already completed for illustration).



- h. Slowly move the Roller Welder along the heat shield, approximately **1 cm per 5 seconds**. The roller edge should follow the edge of the captured fiberglass. Be careful not to pause too long in one position or a melted hole in the membrane might result.

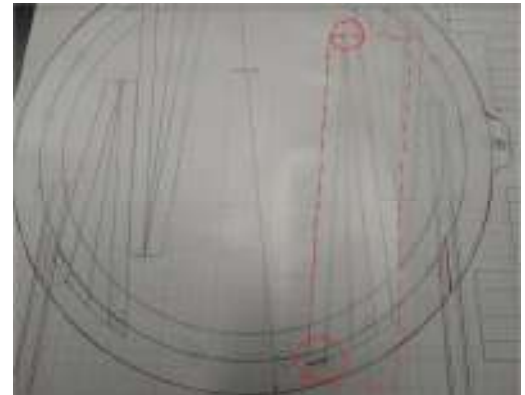


- i. Carefully remove the heat shield (pulling too quickly will tear the membrane). Reposition the captured fiberglass edge along the weld edge, and repeat the weld for the remaining un-welded portion of the Baffle.



6.2 Bottom Baffle Weld #2

- a. Place the 'B' membrane over the 'Bottom' template. Position Baffle #2 (long cut piece) over the corresponding baffle location (red dotted lines). The weld seam should be on the left, with the excess baffle flap toward the 'B' tab as with Baffle #1.
- b. Align the dot on the Baffle with the corresponding dot on the membrane (upper red circle)
- c. Align the edge of the Baffle with the template line, and mark the Baffle as shown in the lower right circle
- d. Carefully cut the Baffle as shown, and reposition the Baffle and 'B' membrane on the silicone welding mat.



- e. Weld Baffle #2 as described with Baffle #1



6.3 Bottom Baffles Welds #3 and #4

- a. Repeat the marking, cutting, and welding steps for Baffle #3. Note the direction the top of the baffle is trimmed.
- b. Repeat the marking, cutting, and welding steps for Baffle #4. All baffles should be welded on the left side, with the baffle flaps on the right side (toward the tab). Note that all trimming should be performed so that the baffle flaps overhang the outer edge of the 'B' membrane.

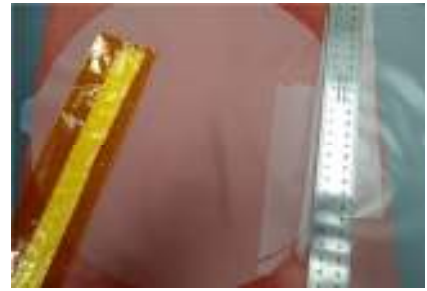


6.4 Top Baffle Weld #1

- a. Place cut 'T' membrane over the 'Top' template
- b. Flip the 'B' membrane over so that the 'T' and 'B' tabs are together.
- c. Baffle flaps should now be pointing left toward the 'T' tab, as shown outlined with red dotted lines
- d. Fold back 'B' tab to expose Baffle #4
- e. Align Baffle #4 on template as shown with the red dotted lines.
- f. Mark the baffle with a dot at the location of the upper red circle, corresponding to the dot on the 'T' membrane
- g. Mark the baffle with a trim line shown by the lower red circle, following the 'T' membrane as a guide



- h. Marked baffle should appear as shown. Carefully trim the baffle with scissors along the marked line.
- i. Weld the baffle following described welding procedure. The metal ruler is helpful to avoid damaging the folded 'B' membrane with the roller welder.



- j. Trimmed and welded baffle should appear as shown



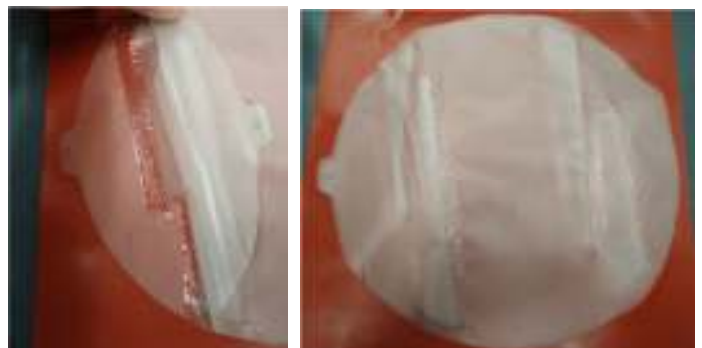
6.5 Top Baffle Weld #2

- a. Unfold 'B' membrane to expose the next baffle
- b. Use the 'Top' template to mark the baffle as before
- c. On the silicone welding mat, align the baffle and 'T' membrane dots as well as possible. The 'B' membrane must be twisted considerably to achieve this alignment, so the metal ruler held in place with heavy weights helps to keep the baffle in position while welding.
- d. Trimmed and welded baffle should appear as shown



6.6 Top Baffle Welds #3 and #4

- e. Repeat previous steps for the remaining baffles.

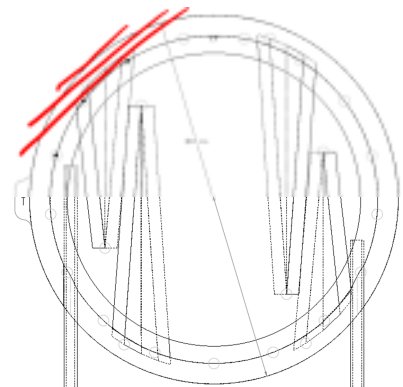


6.7 Outer Edge Welds

- a. With the membrane assembly on the silicone welding mat, carefully flatten and smooth out the end of a top baffle end (red circle). Try to align the outer edges of the 'T' and 'B' membranes at the same time.



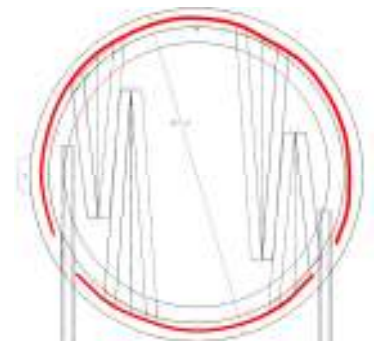
- b. The screenshot shows the 'tangential' weld pattern for the outer edges. The dots around the membrane perimeter mark the inner limit of the welds (black dots shown at right). Three welds are made, starting at the inner limit to outer edge.



- c. The next welds are performed along the next set of dots in the perimeter, as shown.



- d. The outer rim should be welded everywhere shown in red. Any extra membrane material should be bunched toward the tubing entry points so that no folds or creases occur in the outer rim weld at any point.



- e. Starting directly over a baffle edge (inside the 'T' and 'B' membranes), align edge of the heat shield captured fiberglass with two dots. Make three straight-line welds as shown in step 'b.'

- f. Shift to the next set of dots and repeat the procedure all the way around the perimeter, stopping at each tubing entry point.



- g. Test-fit the tubing into the welded pad to ensure the tubing slides in



Section 6 – Tubing and Testing

6.1 Tubing gluing

- a. Cut one piece of tubing to 50 cm long
- b. Fit one tubing end into the opening in the pad furthest from the 'T' and 'B' tabs. Tubing end should be approximately 2.5 cm to 3 cm within the pad.

(Note: This tubing will be referred to as the 'short' tubing. Consult the membrane templates for proper short/long tubing locations if in question)



- c. Use small spatula end to insert adhesive between tubing and membrane, so that the tubing is completely sealed to 'Top' and 'Bottom' membranes



- d. Use hemostats to clamp the membranes together to prevent bubbles from forming along the sides of the tubing. Allow the adhesive to dry

(Note: Membrane edges may peel back after adhesive is applied. Try to re-attach the membrane edges to the tubing)



- e. Cut a second piece of tubing to 60 cm long (this is called the 'long' tubing)
- f. Fit one tubing end into the other pad opening. Tubing end should be approximately 11 cm to 12 cm within the pad.



- g. Insert adhesive between tubing and membrane as before.
- h. Use hemostats to clamp the membranes together. Allow the adhesive to dry
- i. With scissors, trim off outer pad edges (including 'T' and 'B' tabs) until the pad is neatly circular.

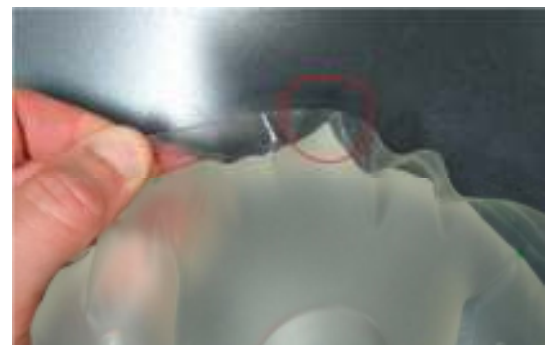
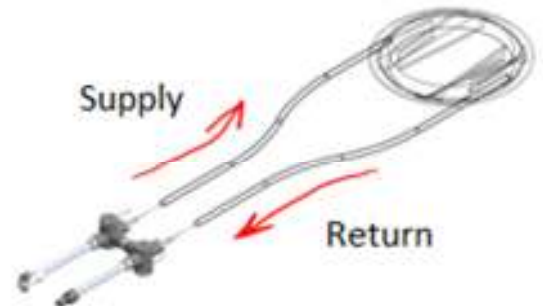


- j. Inspect the glued joints for bubbles that may allow water through the joint. If suspicious bubbles are found, use the hobby knife to cut open the joint enough to insert additional adhesive. Re-glue the joint and inspect.



6.2 Pressure testing

- a. Connect pad to Skin Cooling system supply/return lines for pressure testing:
Short tubing: Supply
Long tubing: Return
- b. Enable Supply flow pump. Pad should inflate to operating pressure, at which point the Return flow pump should engage.
- c. Monitor for drips or leakage from the glued tubing joints.
- d. Ensure that outer seams were welded properly. Photo at right shows an outer seam failure.



– Pad Assembly and Pressure Test Complete –

Appendix – Contact information

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