Alan Rushforth on Building Large Heat Storage Tanks

I have locally built a few dozen insulated solar drainback tanks usually between 1,000 gallons, up to 4,500 gallons, and usually for 20ish to 100ish unit apartment buildings. There are some photos at www.rushforthsolar.com. The bigger the tank, the more the physics 'push' for that tank to be round. The initial thought for many do it yourselfers seems to be to start with 2x4's and plywood. If you can shift thinking from wood to a sheet metal ring, then the larger tank structures become a LOT simpler, and having a simple, efficient, long lasting structure is a very good start.

Admittedly the round aspect may make some other portions of the project more challenging but still doable.

To build big cylindrical tanks (up to 10' diameter and 7'10" tall), I use 48" aluminum coil stock .050 or .044 thick which I ordered in bulk coil. Being able to roll out 32' for a 10' diameter tank keeps seams to a minimum, but such tanks can be made from 4x8 or 4x10 sheets. Hopefully do-it-yourselfers might be able to track down some aluminum or steel sheet metal locally. When I did the hoop stress calculations on early tanks, I had a factor of safety typically way over 4 (and I read in an Alcoa manual 4 is recommended for tank applications that can burst).

I lap the joints 10 inches and run 3 rows of small bolts to create a continuous ring. Once I have the ring the next step is to install a first layer of 1.5" iso foam around the inside wall. (score it every 4" or so, so it will 'bend'). I have found the last pieces can be cut an inch or so wider than seems will fit, then one creates a little V-peak and 'pops' it into to place so the foam

compresses itself all around. It helps to have 2 people for these steps – one in and one out. Then I push a pre-cut round 3" foam floor into place which rounds out the tank very nicely. Then I install a 2nd layer of 1.5" foam around the inside wall, again scored every 4" or so with last pieces v-popped/compressed into place. Then the top foam edge is trimmed along the top as needed.

Next is the liner. I lay the EPDM out in the back yard and position a weighted pin at the center (a piece of flagstone with a screw head protruding up.) To that screw head I hook a tape measure and with a felt tip marker or lumber crayon, draw the outer circle where the EPDM will be cut.

While in line drawing mode, I also draw and inner circle that will correspond to the bottom corner outline of tank floor. It is helpful to also draw 8 criss-cross lines dividing the circle into 8 pie shape pieces. Later when installing the liner, the inner circle line makes it easier to get the liner properly centered in the tank. One then locates a pie cut line, holds the line up against the tank wall so the line is vertical and then pins the EPDM into the foam at the top. One repeats 7 more times and you then have the liner centered and pinned at 8 points around the tank but not yet looking pretty.

Nest you put on your upholsterer cap and make interim folds nice and neat and even. When done folding and pinning the liner all around the top perimeter of the tank, the liner (which was pre-cut a couple inches oversize) will over hang the tank a bit. Then with a sharp knife, I trim off the excess liner so that it the edge of the liner is even with the aluminum outer wall. The photo at right shows the folding and pinning done, and you can see a knife blade working its way around the edge.

LID CONSTRUCTION: Building the lid is probably the trickiest part of the tank. After trying a few approaches, I now use 3” iso roofing foam (available from a good commercial roofing supply) for about $35/sheet. This is the yellow foam with dark grey or black paper/felt on each side. This 3” foam for the lid gets cut into a circle with a slight inward taper on the cut (like a cork is tapered). Let’s say you want to build a tank with an 8’outside diameter. After 2 layers of 1.5” foam are installed inside your tank, your inside diameter would be about 7’6”. After folding and pinning your EPDM liner into the tank, the i.d. of the tank would now a bit smaller - maybe 7’5 ½”. I would cut the top of the ‘cork’ about 7’5 ½ ” diameter at the top and it would be approximately 7’5” diameter at the bottom. I use a jig saw with long blade for that cut.

Since the foam comes in 4’x8’ sheets, how does one best make a 7’5” diameter circle? The technique I use is to edge glue 2 sheets of foam in to one big 8’x8’ sheet first use can foam (Great Stuff or equivalent). I lay a polyethylene sheet on the floor, then layout the 2 sheets of 3” iso foam, then apply the edge glue to one edge. Then slide together. To secure the 2 sheets from moving apart as the can foam sets, I press across the seam some plywood scraps with small nails sticking out. This grabs the 2 pieces of foam and stops them from moving apart. Some weights on top help too. A couple hours later you have a big 8’x8’ foam sheet that holds itself together while you draw your circle and then cut into a nice round cork shaped lid. I have made round lids up to 10’ diameter with this technique.

Then I next laminate EPDM onto the top and bottom of the lid. One could probably use contact cement (like EPDM roofer installers use). Personally I like 1 part can foam. With the plastic straw removed, I spray the can foam out on the sheet foam, then quickly roll out the spray foam with a cheap roller on a pole, then quickly lay the EPDM in place and then roll back and forth with a linoleum roller for 20 minutes or so while the foam cures. The foam tacks up quickly so you want to be

organized and keep moving once you start.

The photo at right shows the process of rolling out the can foam. In this case the lid is being made of 2 semicircles that will connect and hinge in the center. It gets more complicated to make a hinged lid, but it can be necessary if the lid diameter gets taller than the door opening height. A single rigid circle is easiest to construct.

When laminating the EPDM it is helpful to do it the way linoleum is installed. Lay out the EPDM in exactly the location you want it, make any cuts or adjustments, then carefully fold back one half, apply glue (can foam rolled out), then quickly and carefully replace the EPDM. I give it an initial roll with a linoleum roller, then quickly peel back the other half, apply can foam, roll out, replace the EPDM. At that point, I will roll the lid repeatedly with a linoleum roller for 20 minutes or so until the foam sets up.

I have found the can foam is very compatible with the grey paper/felt backing on the iso roofing foam, and it bonds very nicely.   In tests I have found water based glues (like most linoleum glues) can soften the grey paper/felt and make a less satisfactory bond. Also if any small amounts of moisture were to percolate through the EPDM over the years, I like the idea of using a glue (like the can foam) that is impervious to moisture.

Once you have EPDM laminated onto the top of your round lid ‘cork’, then you can flip the lid and laminate what will be the underside of the lid. If you are building the lid in your basement, and your basement ceiling is say 7’ high, keep in mind if the lid is more than 7’ high, you may not be able to flip it over.

Once flipped and the 2nd side is laminated and rolled out and set, then one needs to deal with the edge. I insert a little more foam around the 3” edge of the big foam cork (under the upper layer of EPDM), press the upper layer down against the 3” sides of the foam, and pin the EPDM sideways every foot or so with 3” stainless roof nails. I flatten out the remaining 4 inches or so of EPDM against the floor and against the first layer of EPDM that is protruding out flat along the floor. Then I take a 2” truck ratchet strap (or 2 straps hooked together if extra length is needed), wrap it around the 3” edge of the lid, and snug up the ratchet strap. This compresses the edge of the EPDM up tight against the edge of the lid/cork. You have to keep moving quickly through this process as the foam will set up in 20 minutes or so, and you want to get this strap on and snugged up before the foam sets. For good measure after the strap is on, I compress the 2 layers of EPDM that protrude out around the perimeter with a row of bricks, so if any foam worked its way in there, they would be weighted together flat as the foam sets. The photo shows a lid laying on the floor after this edge treatment with ratchet strap snugged up and bricks in place.

At this point, if you did it right, you have a sturdy round lid with lip, ready to be laid over your tank and jammed into place. It will take a fair amount of labor to build, but the material costs would moderate. If you cut the EPDM for the lid right, it will overlap the tank by an inch or 2 once jammed in place, and you just trim that excess off with a sharp knife.

There are lots more details that could be expounded upon, like top cross brace tubes that support the lid and heat exchangers, and PVC sleeves that the top cross braces insert into.

For now I will just comment a bit on heat exchangers that can go inside the tank. The photo at right shows an installation with submersed pressure tanks used as heat exchangers. One might think that if you have sufficient tank surface area, this

approach could work efficiently as the heat exchange process would continue between the sporadic water uses. The approach does work, but appropriate pressure tanks are a bit hard to find, not cheap, and our data monitoring shows that during periods of sustained heavy hot water use, the preheated water in such tanks will get flushed out. Data from other systems shows that coils with the same surface area in similar flow conditions perform better. I suspect that is due to the fact that the water inside the pressure tanks would be very slow moving compared to water in the coils which would move much faster, scouring heat off the heat exchanger walls more effectively. Another possible downside to this submersed tank approach is there are quite a few joints inside the tank. We have yet to have any of these submersed tanks or joints leak, but if/when they do, it will require draining the tank to access and repair.

Ideally once the tank is erected, one would be walking round in it as little as possible. This approach of submersed tanks does involve a fair amount of plumbing work to be done carefully inside the tank.

Here is a photo of another approach of copper coils installed in a tank. These coils are wrapped around the perimeter of the tank, suspended on stainless steel tubes attached to the top cross braces. There is no stainless to copper contact as the copper tubes are supported by plastic pipe hangers that are strapped (with stainless band clamps) to the vertical stainless support pipe. This approach works well. Downsides are there is a fair amount of plumbing labor to be done inside the tank that must be done with care to not damage the lining. There are some connections inside the tank that will involve tank draining if/when they need repairs. As we all know, copper is expensive, so that is another downside of this approach.

My preferred approach is corrugated stainless steel

(CSST) coils. Yes, stainless steel has lower thermal conductivity than copper, but I have found CSST coils can work wonderfully not withstanding.

On say a 40 unit building, in the past I might typically install 3 or 4) ¾" dia. x 60' long copper coils in parallel. I have tried larger diameter soft copper, but it can be extra expensive plus quite unweildy to work with. CSST is lighter, easy to bend, and the 1" i.d. size (1.25" o.d.) works out to a particularly good value. I have used 2) 1" x 100' csst coils in parallel in 40 unit apartment buildings, and the data shows those 2 coils pretty much (within a degree or 2) bring the water exiting the coils up to the temperature of the top of the tank, as well or better than 3 or 4) ¾" x 60 copper coils. 2 CSST coils entail less plumbing connections than 3 or 4 small copper coils. The CSST is more reasonable in price than copper especially if one orders several coils at once. If one is just ordering a small quantity, than shipping costs may become more of an issue. We have purchased from Easyflex.com. They also offer reasonably priced reliable fittings to adapt to copper or pipe thread.

If you have worked with soft copper, you have experienced how (within reason) it will bend and flex and twist in any direction. One weird minus with CSST is that though it can be bent into a curve more easily than soft copper tubing, CSST has essentially has zero ability to twist around its longitudinal axis. If you ever try to make a helix coil with CSST you may find yourself becoming very frustrated how it can be very 'obstinate' and refuse to 'work with you'.

From building earlier copper tubing helix coils, I had a 14" diameter x 6' long sonotube rigged onto a slow rotating horizontal pipe threader machine that I had used to coil soft copper into nice 18" diameter helix coils up to 6' long. Copper was very forgiving to use on that machine. I could hold and unspool the factory spool of copper in my hands as the sonotube slowly rotated and wound up the helix coil. I found that to use CSST on that machine, that same approach would not work.

I had to rig the CSST spool from a rolling track attached to the ceiling to allow the factory CSST coil to freely move in 3 ways. 1) The factory spooled coil would un-spool on horizontal center axis as you would normally expect. 2) Where the spool attached to the ceiling, I attached it to a sliding door track to allow the spool to move laterally along as the spool worked its way down the sonotube (again easy to envision). Finally, where the spool of CSST attached to the ceiling track, the attachment had to be able to pivot on its vertical axis as the factory spool of CSST unwound and re-wound onto a spiral helix around the sonotube. The top spool would insist on slowly twisting about 1 revolution on its vertical axis as the helix below was wound up on the sonotube. A little hard to discribe, but bottom line CSST flexes readily in certain ways, but is totally uncooperative when you try to impose any torsional twisting on it.

All that said, I favor the CSST coil approach for heat exchangers in these EPDM lined tanks because CSST coils work well, they are light, they can be less expensive than copper, it is possible to pre-make the coils and then easily hang them inside an assembled tank.

Gary gives a link for an old tank page on the Rushforth Solar website below that gives rough pricing for some installed tanks. At the time that page was created it looked like we might be installing more of these tanks for other companies. At this point we should probably take down that page as we are not pushing them and have found no demand for these installed tanks.

It should be possible for may strong willed do-it-yourselfers to build such tanks for a small fraction of the prices listed, but for a contractor to do it, pay overhead, make some profit, the prices listed seemed about right.

Hope some of this info might be helpful.

Alan Rushforth, PE
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More on Alan's large tank projects here:

[Rushforth Solar Tanks page ...]

[Rushforth Solar Projects page...]

[Large Thermal Storage Tank with Immersed Tank Heat Exchanger...]