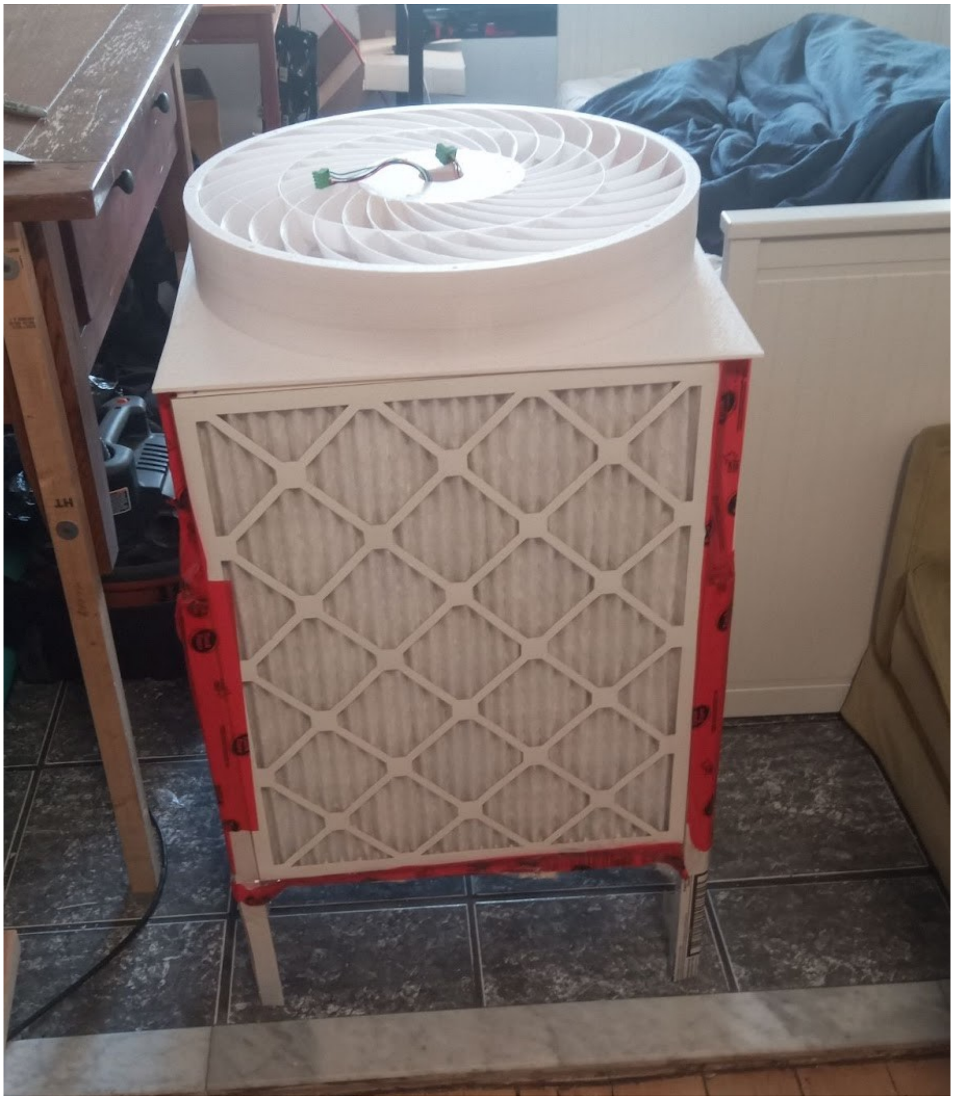
10 Filter filter box ("CR box") with Big Quiet Fan experiment/mock up(s)



Update march 5 2025: This device uses an older model of fan. Considerable progress has been made. It's been in operation all this time and working well. I added a safety feature, a thermal switch, but it hasn't tripped even at full power. During summer at high ambient temperatures that could still happen. The safety margin is a bit slim on that count, but the safety margin against actual overheating is good. Remember this is all only proof of concept, mostly about the blade design and the filter arrangement, to prove high CADR to noise ratios and high cubic meters of air to total $ expended (10x or more higher than the next best, 30x or more than typical air filter units). Also the estimates for the boxes in this document may not be very good, regarding flow rate etc. There were a lot of sources of error back then, they were only estimates. These filters are also on the crummy side, lower flow rates than filtrete ones. I have since build a better box and it works well. I will build another in due course, but I may return to these crummier filters because they are half the price and that's pretty important. I have also measured a very similar system precisely with a validated anemometer. The latest fan gets 1452 CFM measured precisely with the validated anemometer, at full speed, 400 rpm (47.5 dBa) with 3m filtrete merv 13 filters, and 1111 cfm at 300 rpm (37.5 dBa). That's flow, not cadr.

Edit: to be clear, this fan is 3d printed. It's source, the cad files, are available at openerv.ca as well as information to help you get the rest sorted out. However it unfortunately requires a large format printer. Don't get the veho-600 it's terrible, or anything tronxy. The orangestorm from elegoo looks good.

Intro

I have been working on a window-fan sized fan with the best flow to noise ratio through a set of merv 13 filters I was able to arrange reasonably, as a proof of concept that it's possible and practical to do far better than we have been doing.

I also thought up a way to cram 10 filters into a filter box of nearly the same dimensions as a 5x or 4x box. It has to be lifted up off the ground with legs, like a 5 filter box, rather than sitting on the ground, but that vertical space is not usually used anyway.

The sides should stick out a little more than a 4 filter box, just a few centimeters on two of the sides, to improve flow on the interior of the box. I just made it a square instead, so it sticks out on all sides, to keep it simple.

Edit: move the triple V down some too, that should help.

You might even be able to up it to 12 filters with a quad V.

The key to realizing why this is a good idea is that the cost per cubic meter does not go up when you use more filters, because you get x amount of air per filter before it's "clogged" either way. Or rather, X amount of particulates, and the air passing through in this context has already passed through and thus has very little particulates in it.

But when we have more filters, we can turn the fan down and get less noise for the same flow rate. Efficiency of particle removal might even go up as velocity through the filters goes down. The fan can be lower power, which is cheaper. Fitler changes are less frequent because each filter captures a lower fraction of total particles the machine intecepts. It's definitely a win, except that the upfront cost is of course higher for the larger number of filters. Except now we can use cheaper (about half the price) generic filters instead of the good Filtrete ones or whatever, and still get pretty good performance (the cheap ones do have about 1.5 times the pressure to flow ratio). Also sourcing filters becomes easier for a given performance.

Edit Dec 10 2024: Actually, I think the cost per cubic meter may actually go down when we add more filters. This is because you have a pretty high ACH with these appliances, thus almost all the particulates that can clog the filter have already been removed from the air that passes through the appliance. It's about the particulate matter the filter intercepts, not the amount of air that passes through it, that determines how long the filter lasts before it must be replaced (assuming a given flow reduction is acceptable). But because the particulates released into the room to do not increase when we filter the air at a higher ACH, that additional ACH is relatively cheap - nearly free probably - in terms of filter cloggage/cost. Secondly, though this is not additive or multiplicative with that but could become prominent in some contexts: suppose you need a CADR of X. You can get more particulates intercepted per filter if you have more filters, because each one can clog more before it passes the "time to replace it" threshold, because the sum of all the filters flow is the cadr. Thus if you have twice as many filters, each one can suffer twice the cloggage level (half the pressure to flow ratio) and still be serviceable in an appliance that gives X cadr. Thus, you can extract more filter life per filter if you have more filters, all else being equal. Thus, the cost per particle intercepted or per gram of solid matter removed, actually may go down with more filters, all else being equal.

So, **increasing the number and density of filters is really the way to go,** pretty much a win all around, all else being equal it's going to make things cheaper and quieter for sure, the only downside is it increases the sticker price of the assembly, course. If we assume a certain interest rate on the cost of the filters because we need to buy them today rather than in a year from now, the cost of the expenditure is very small compared to the benefits that accrue along the way. It's a very good investment. So rationally, it's really the way to go. Exactly how much so warrants a spreadsheet to reckon.

You want to try to use the wells-riley equation and some similar approximations to calculate the cost per infection prevented for various appliances. The cost will change for different contexts though. What we really want is an objective metric that calculated the cost per qaly gained, with weighted average calculated for a wide range of scenarios the particular machine is intended for. You would subject each machine proposed to this evaluation and pick the best. I think this fan combined with very dense large filter like this would likely be a winner by a large margin but it would be nice to actually check this quantitatively.
– end edit

In the case where you simply tape together 10 filters, it has the added benefit, and also in other cases, that you, at a flow rate of X, do not need to change the filters as often. Indeed <1/(2.5) times as often, as compared with a 4x box, if we assume they need to be replaced after each filter intercepts x many grams of particulates, and total particulate interception rate is unchanged. We may get more than that because the particulate loading per filter that is acceptable may be higher in this 10x config. Since we have to tape together a new box every time, we'd appreciate this long lifespan. Estimating filter life is difficult but some studies indicate a 4x box had no problem after a year of continuous operation so we might get like 3 years, I don't know. The degradation of the electrostatic media could be a factor at that time scale. What we would ideally talk about is grams of particulates intercepted vs the CADR the appliance gets, and then have a cutoff at say 30% reduction from the new state and see how many years that is. Then we could compare various configurations more directly and reliably.

This box is a big one but the concept can just as well be applied to smaller boxes, you can get filters down to 8 inch size even.

The key is the triple V in the middle, you might even be able to make it a quad V, but I figured this was a good start.

When using crummy generic filters like these, it is particularly valuable, as they impede the airflow considerably more than good quality filters.

I have estimated the airflow with my Big quiet fan, by covering most of the filters, to increase the pressure, measuring the flow rate through the filter with my anemometer, calculating the CFM per pascal, and then extrapolating to the situation with 10 filters uncovered (the pressure is also measured with the same sensor in the 10 filter context).

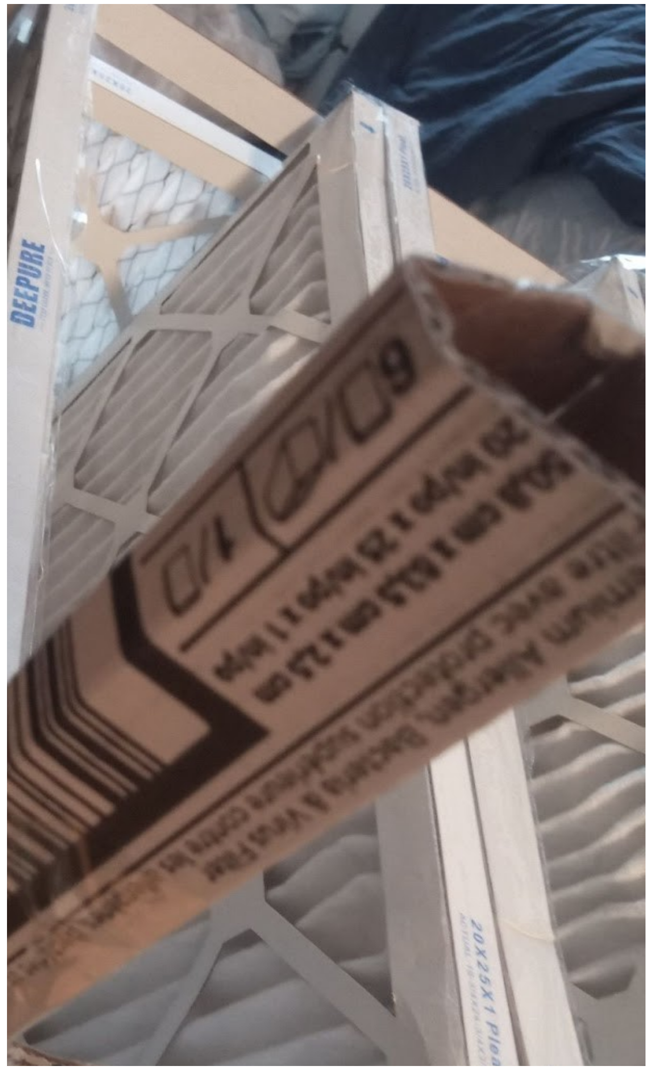
The net flow rate indicated by the instruments was 1475 CFM. If the efficiency is 0.8 then we get a CADR of 1180 CFM. With a noise of 40.6 dBa, according to prior measurements of the fan at the same RPM (300 rpm). However I suspect my anemometer may be reading a bit on the high side. I am looking for someone with more sophisticated test equipment.

It occurs to me you could replace one side with another fan. **Basically you are condensing 2 to 2.5 filter/cr boxes into one, approximately.** Not a bad trick really.

Steps:

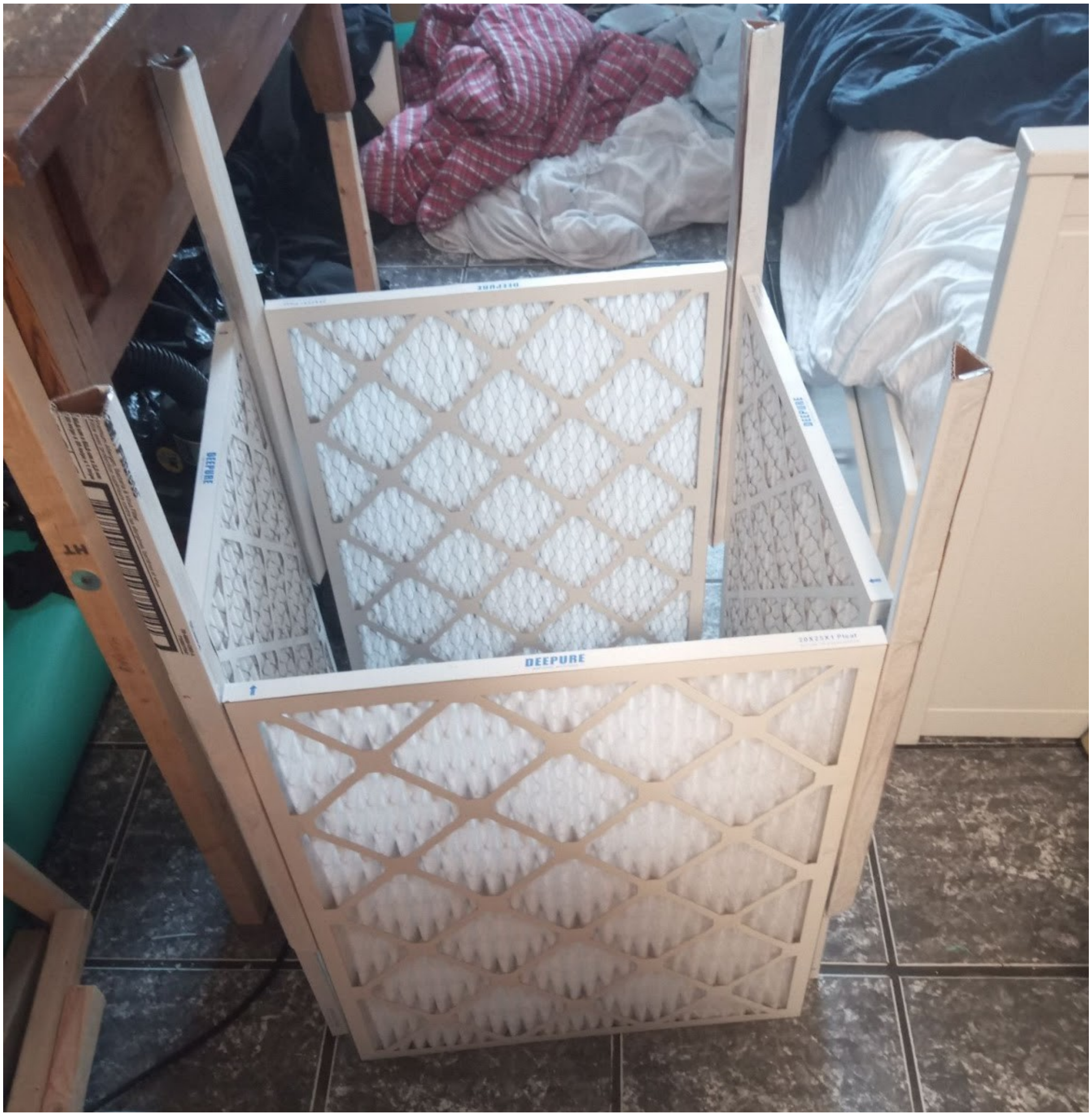
> First we are going to make the legs out of cardboard. I tried to make them right angle triangles but my precision was a bit poor and I think square might be better. Cut strips of cardboard about 500 mm long and 15 cm wide. Then fold them along the corrugations at three lines spaced equally apart with a straight edge, and tape them. I forgot to take

pictures of this step but it’s pretty straightforward. Mark the stuff with a straight edge and

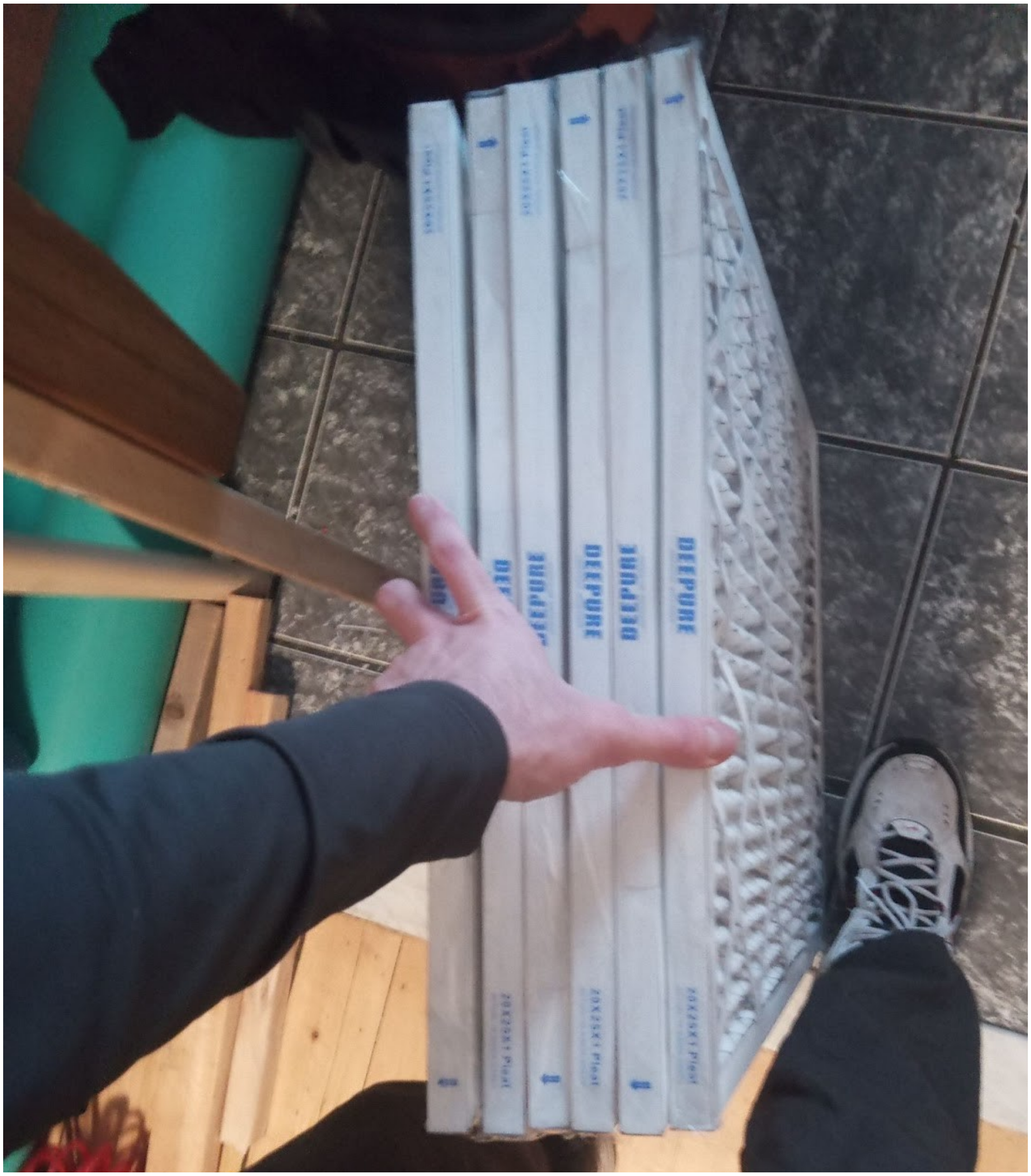


marker then cut with a box cutter.
Mark the legs at about 200- 250 mm, but all in the same position from their ends, with the marker, we will use this to help position them later
Tape the peripheral box together, I went around with the tape, attaching the filters and legs at each corner successively. It helps to put a bunch of tape pieces on a nearby table so you can hold stuff with one hand and grab tape with the other. Don’t worry about

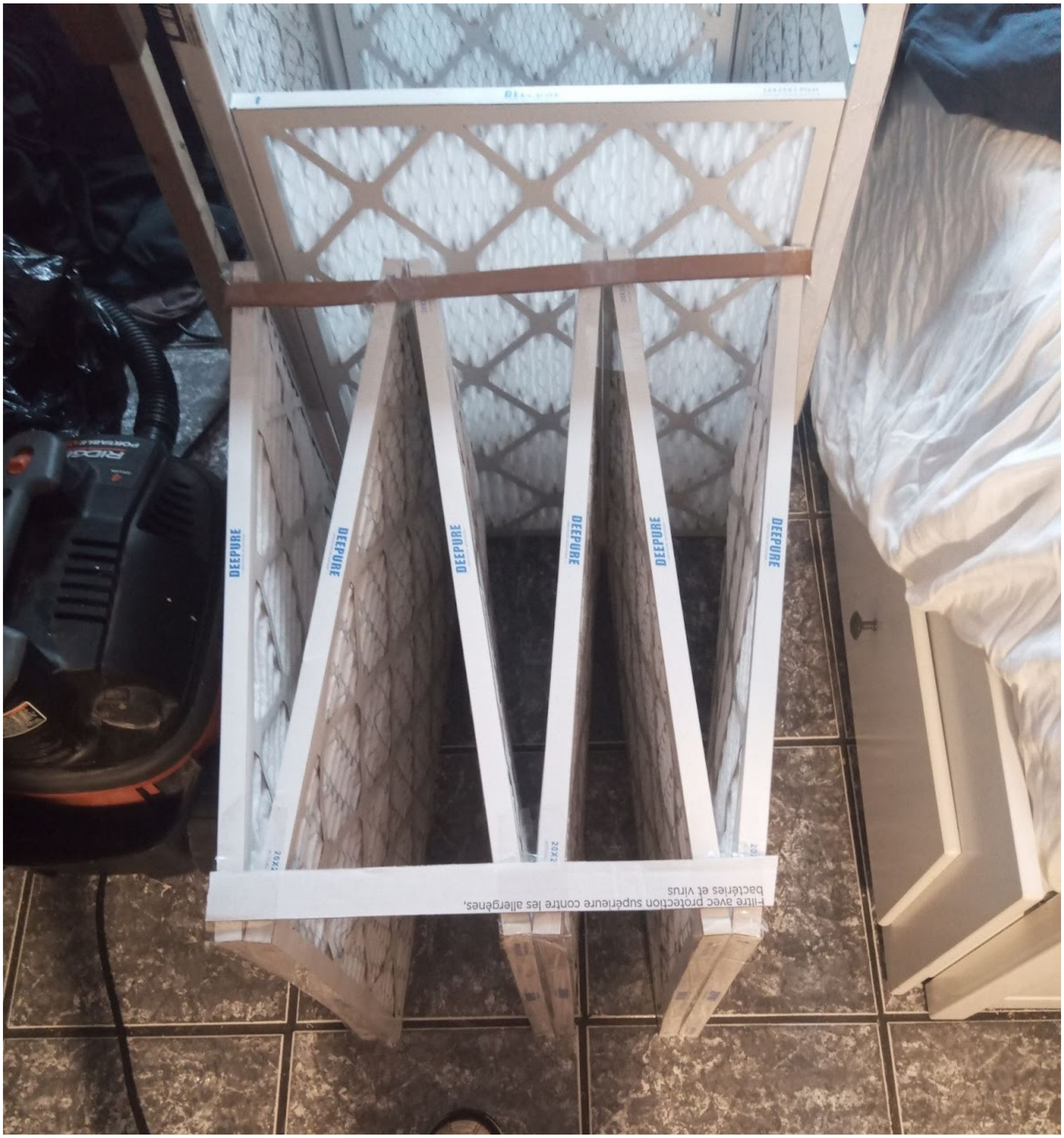
sealing anything yet, we get the structure together first and then we seal stuff.



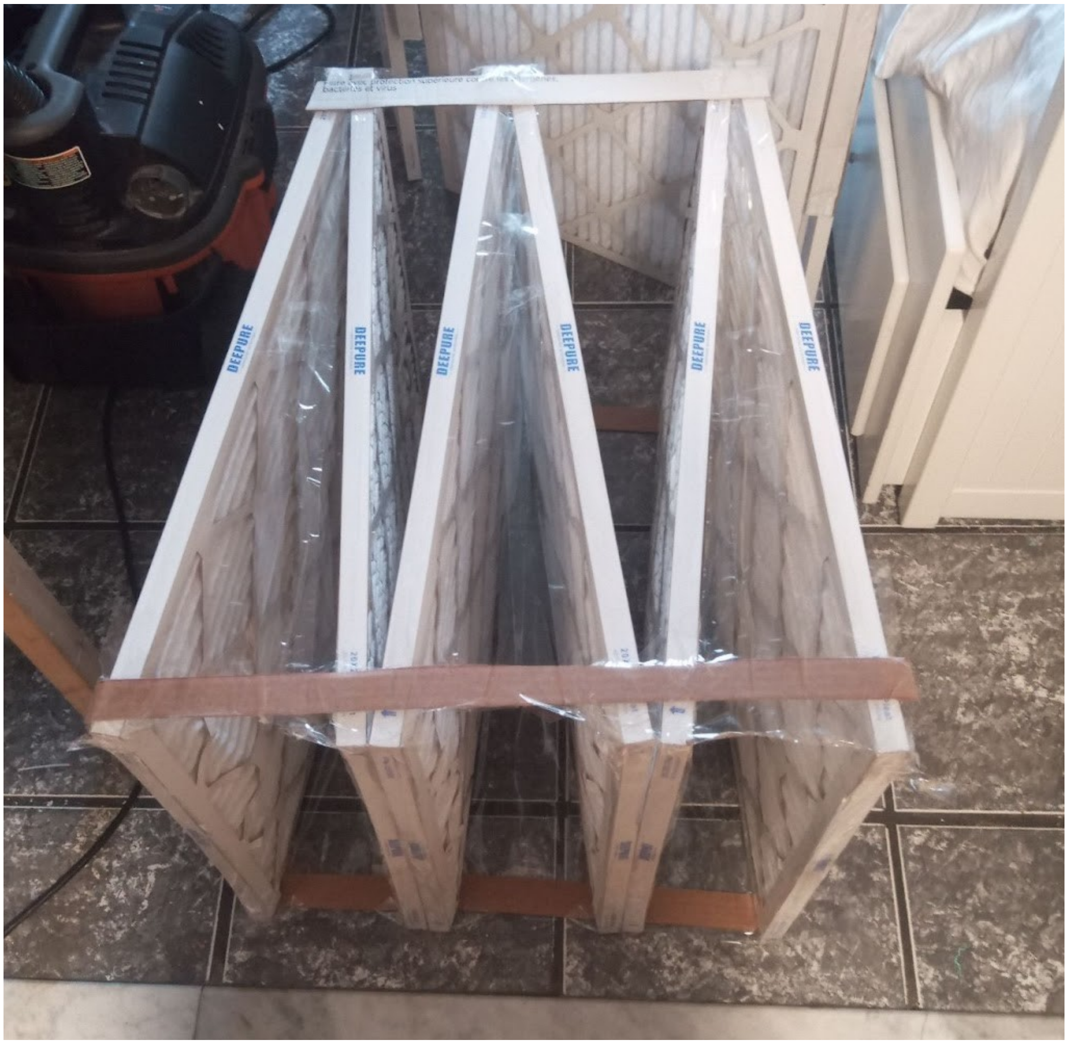
Next, we need to prepare the triple W insert. Start by arranging the filters in the right way, the arrows to indicate direction of flow should be right. The outer two point outwards, then the ones in between alternate.



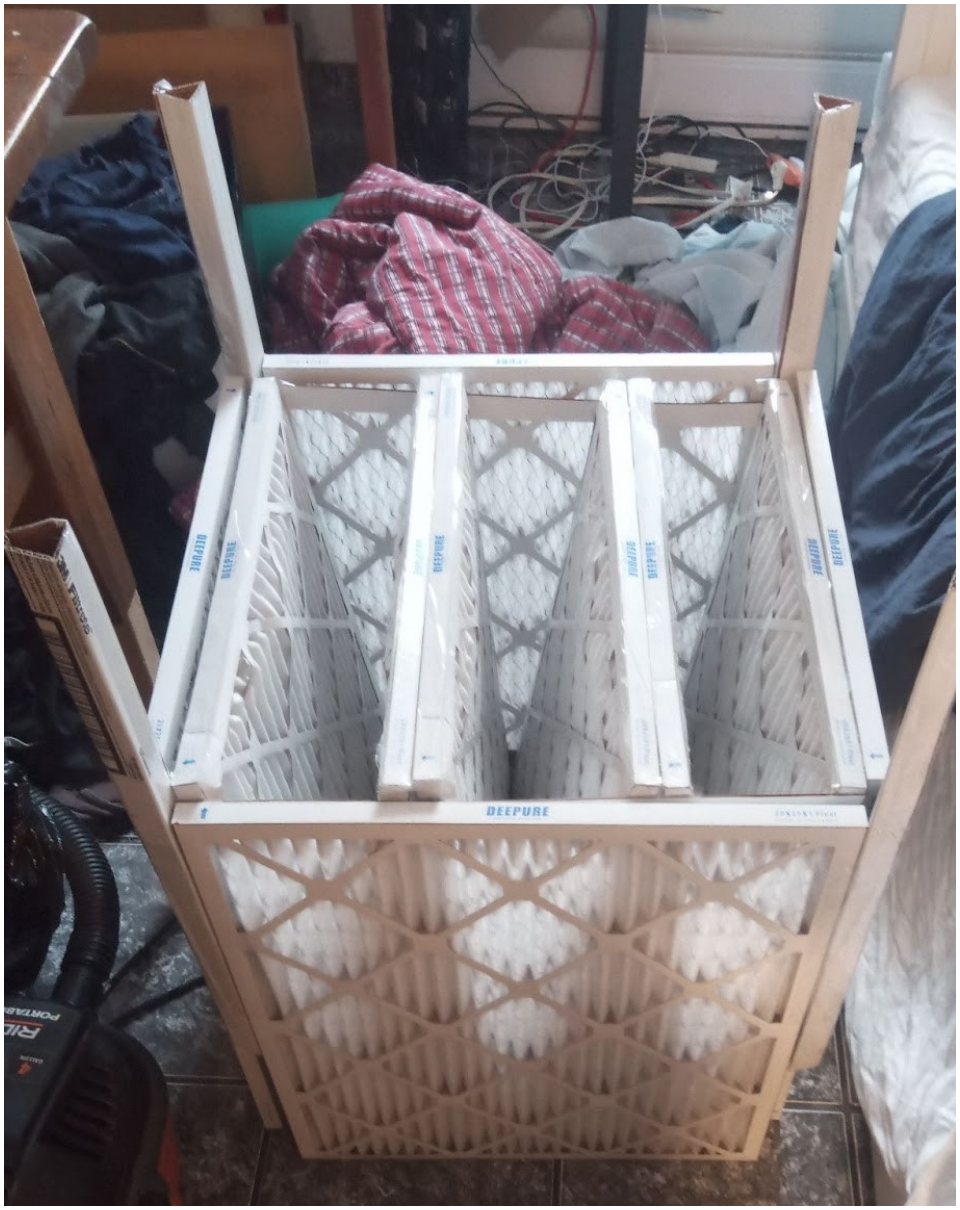
Just tape all the edges together, don’t worry about which ones to tape and which ones not. The edges of the tape stick anyway. Just tape it all up and then cut it in the right places with a box cutter. I then attached some strips of cardboard to hold things in position. Measure it against the nearby square box thing to make sure the VVV is the right width etc.



Next we block off the relevant areas in the Vs with tape. On the wide end it’s going to stick out so the tape doesn’t have to extend to that area

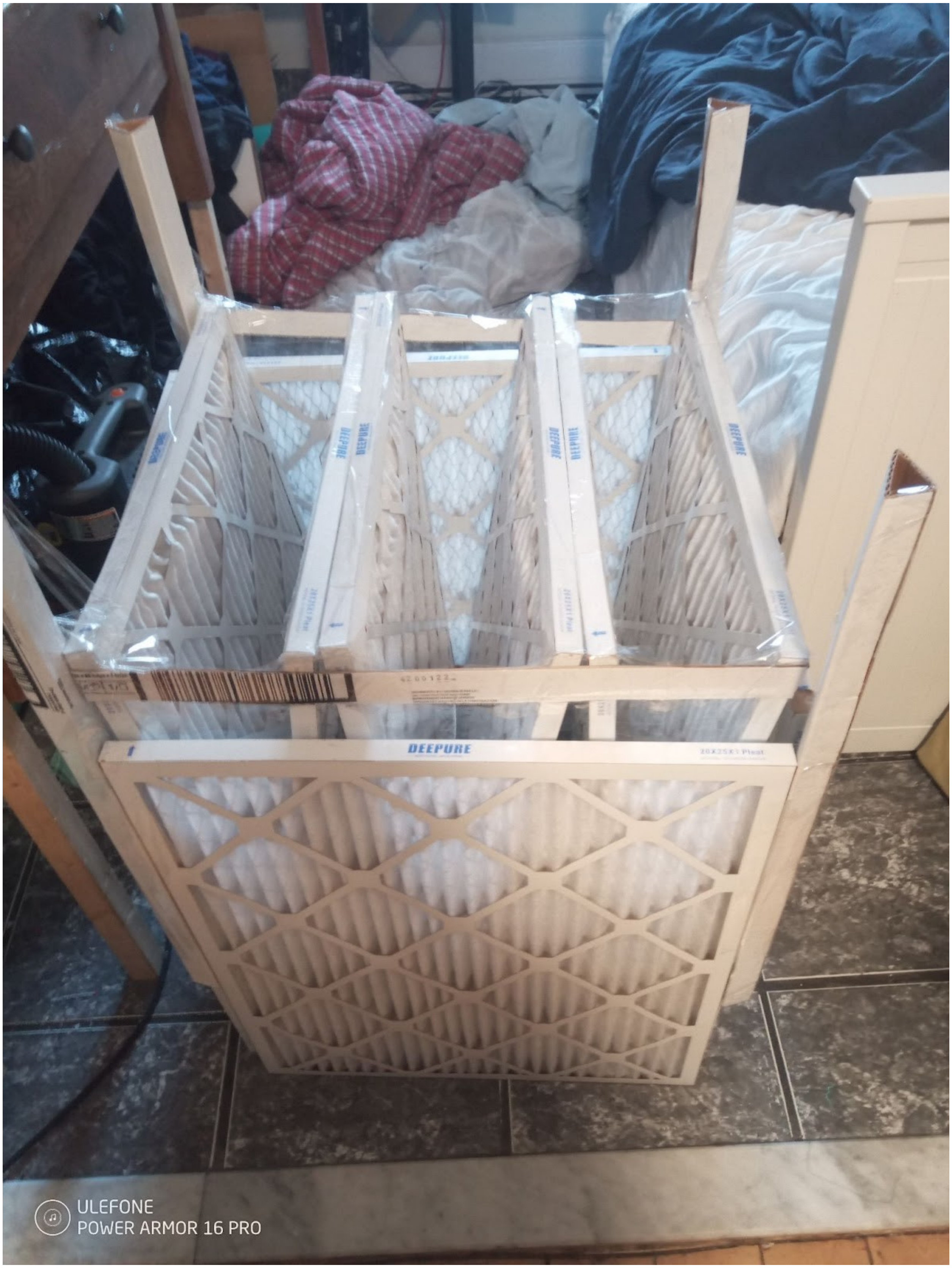


Now we can insert this component into the peripheral box to make sure it fits. But we want space at the end for air to flow, so I’m going to back them out a bit, whether this is necessary I don't really know.

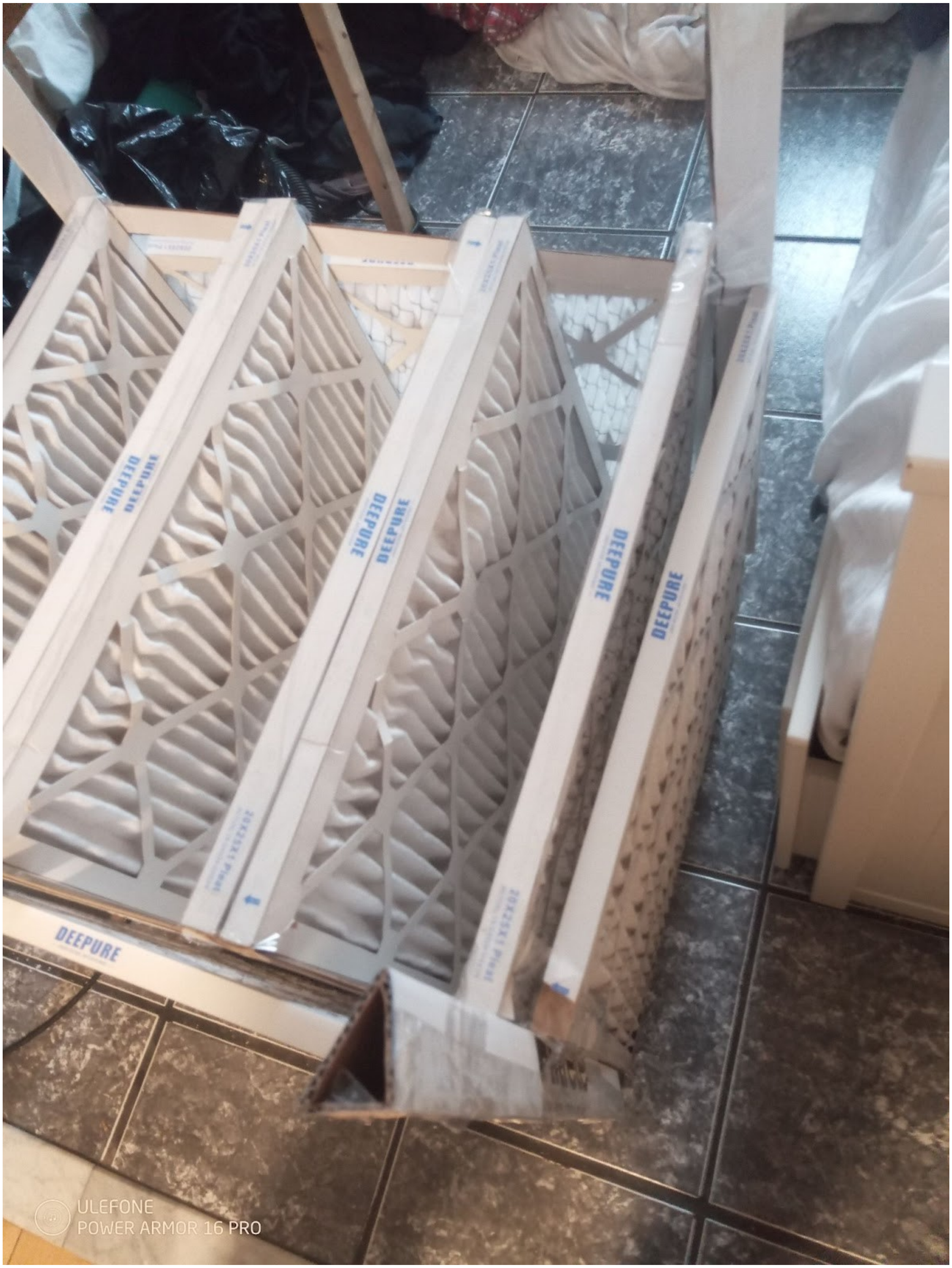


Tape the triple v thing in position and then seal around it. *notice that it is not flush with the bottom of the peripheral filters*. This extra space is important for air to flow around.

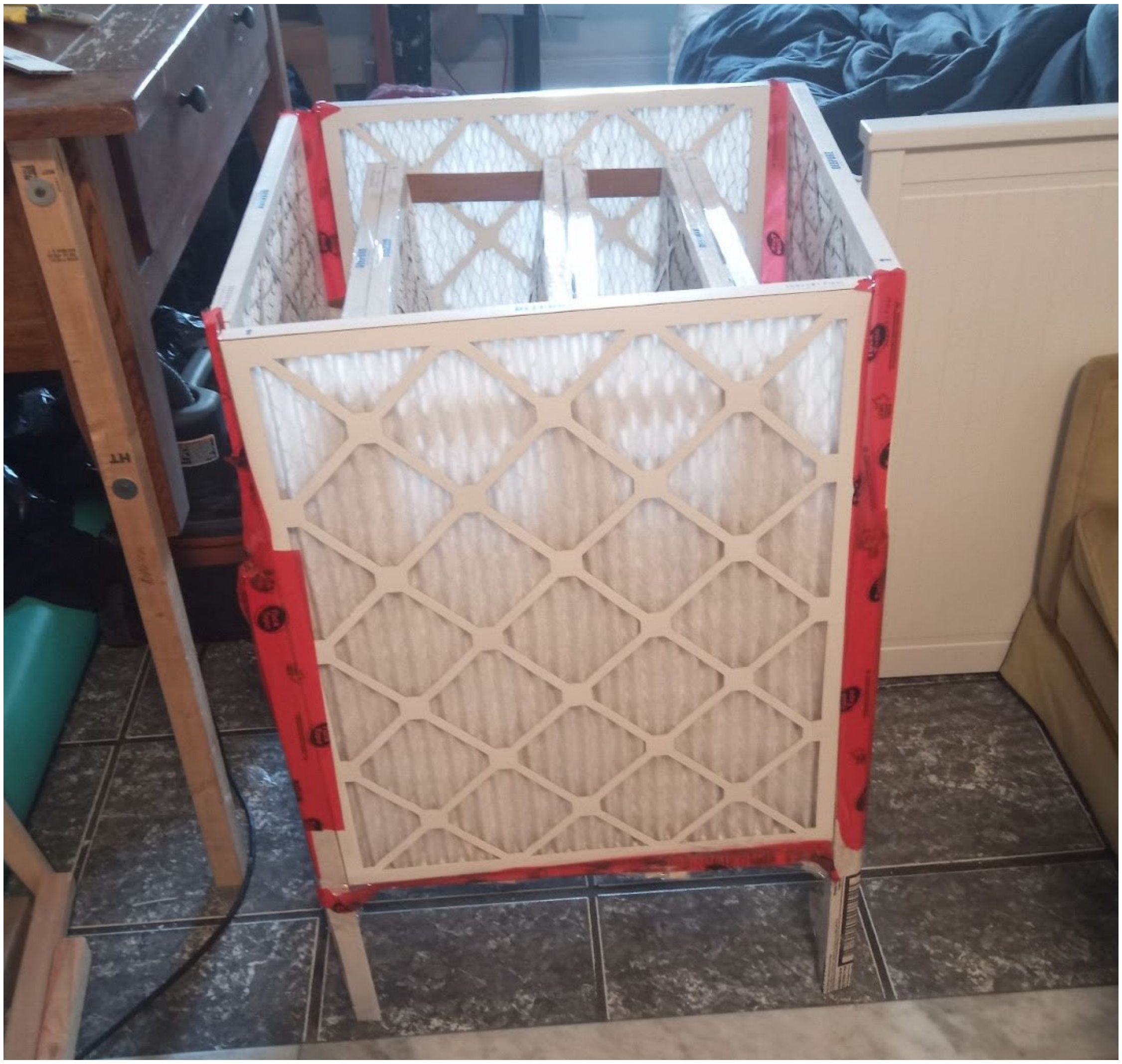
I would increase it next time.



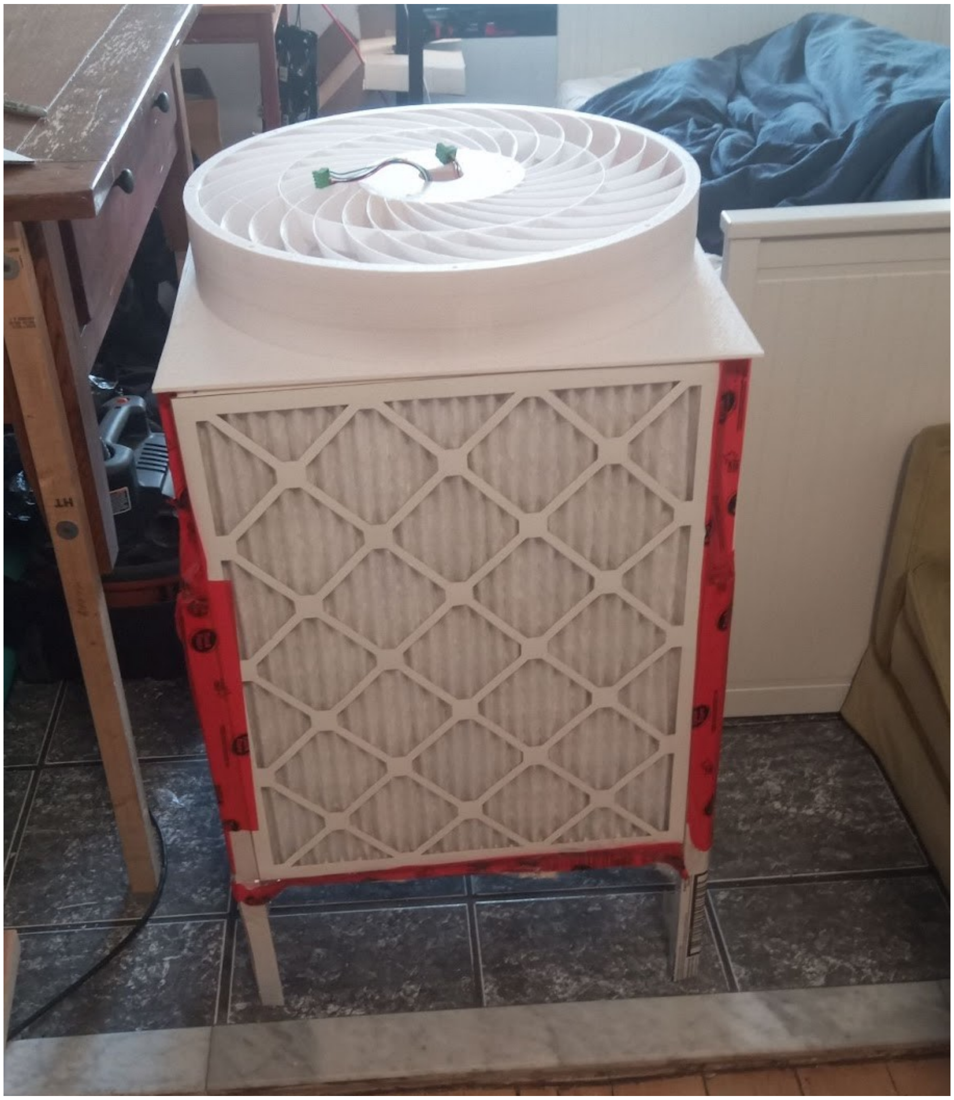
Hard to see the tape in the pic but I ‘m pretty sure this one is sealed.



Now you can turn it right side up and if necessary, trim the legs so it is level. Oh and tape the rest to seal it. I ran out of packing tape so I used tuck tape.



Now you can simply plonk the fan on top, I am not taping that to seal it because it's just a test.   This fan shown has no power supply attached, I'm just showing it. Again, this particular box is quite big, very large capacity, but you can use the same general pattern for a much smaller box.



This filter box has now been assembled and installed and been operating at Foulab. Someone kicked the leg apparently, the cardboard legs are not a good approach, they should be timber, hanging it from the ceiling or putting it on a table or something would also be a much better idea. The next one I put on top of a fridge.