Bill Edgar's experience building a solar hot water system:

I was inspired by Gary's $1000 domestic hot water system (http://www.builditsolar.com/Experimental/PEXColDHW/Overview.htm) and studied it quite carefully. It got me thinking about building my own system. I appreciated the information very much on his web site and have used it a lot! My circumstances were different in several ways from Gary's so my design ended up taking some paths of its own.

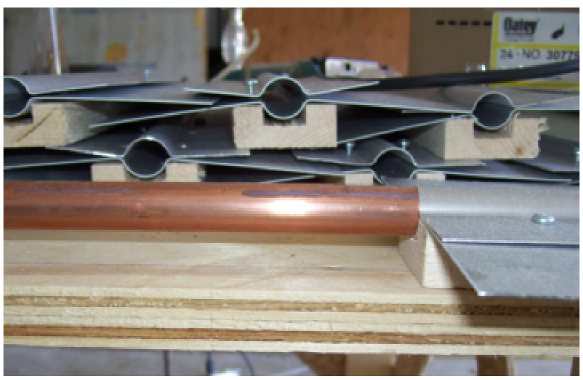
The collector:

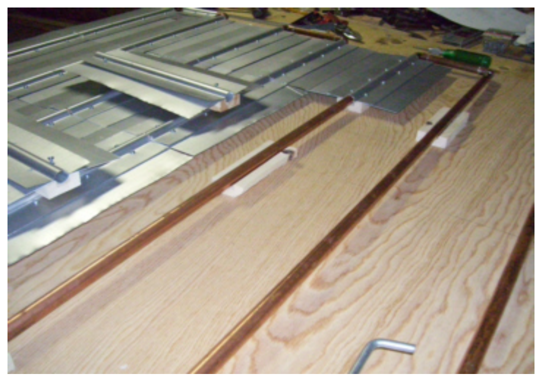
I live in a wooded area and my wife and I could not find a place where we could put the collectors on or near the ground and still get decent exposure. I reluctantly decided that a roof mount would be the solution. Certainly after having built it I don't recommend a roof mount unless you really have to. Its more complicated and costly since it has to have its own substantial mounting system well connected to the structural elements of the roof - I don't recommend just attaching it to the roof sheathing but into the trusses. It's more dangerous since you are working on a sloped roof and going up and down a ladder and more difficult to install since you have to hoist the collector onto the roof. Putting the plumbing in was also more difficult and in the end I gave up on a drain back design partly because of the height of the collector which would have required too large a pump to start against all that head. Also it would have been very difficult to maintain a nice sloping system going through the attic and roof to ensure no water stayed in the lines when draining.

After doing a simplified spreadsheet analysis of heat losses in the collector I decided to go with twin wall polycarbonate glazing of 10 mm or 3/8 inch on the front and 2 inches of polyiso insulation behind. Both these were difficult to obtain where I live (New Brunswick, Canada). In fact to get a reasonable price on the glazing, I bought it in Ottawa (1200Km away) while on a family trip and brought 5 sheets of it back on my cars roof rack.

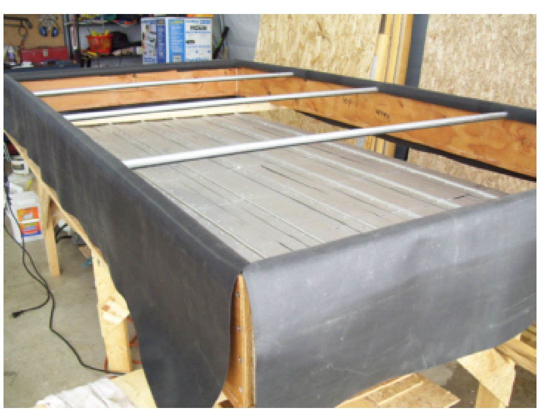
Next I looked at how to connect the fins to the copper pipe and that in turn to the collector frame. I looked at the amount that the copper pipe, the aluminum fins, and wood could expand. Using a delta T of 75 degrees F on an 8 foot run I got 1/16 inch for copper, about 1 1/2 times that for the Aluminum fins and hardly anything (1/100 inch) for wood. I wanted to make sure that the aluminum fins would not work loose, over the years, from the differential expansion of wood and aluminum. Instead of using staples to hold the fins down on a plywood backing, I opted for screws that fastened an upper fin and a lower fin onto a piece of spruce (see photo). Each set of fins and its spruce holder was only 12 inches long. The Spruce holder had a large groove running its length that accommodated the lower half of the fin and pipe. Below that was a sheet of 1/4 inch fir G1S plywood. Small screws connected the spruce holder to the plywood. The holes for the screws in the plywood were oversize and the screws were left a little loose allowing the pipe and fin assembly to expand and contact at will. When assembling the fins to the pipe I put a bead of silicone caulk along each fin following Gary's idea.

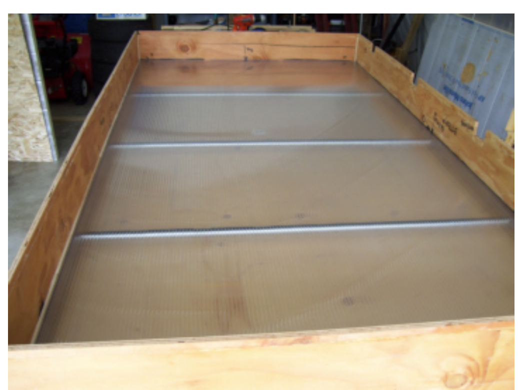
I noticed that the zinc plated screws I used started to rust within weeks of operation. This was probably due to the high humidity in the unit which I talk about a little later. My next collectors will use stainless steel screws and anti-seize compound to try and fend off any corrosion that may happen when dis-similar metals like zinc plated screws and aluminum fins come into contact in the presence of an electrolyte which was the water in the air.





For reasons of economy, I built the collector frame out of 1/2 inch plywood and covered it with EPDM rubber sheet that I had left over. Given the flimsiness of the frame I opted for and built a stressed skin panel made up of The 1/4 inch ply on top (mentioned above) then the 2 inch polyiso insulation and then a sheet of 1/4 OSB for the back. Long 3 inch screws sandwiched these elements together. I cut small blocks of 1/2 inch plywood which were glued on top of the 1/4 sheet. These were what the 3 inch screws screwed into from the OSB side (see photos).

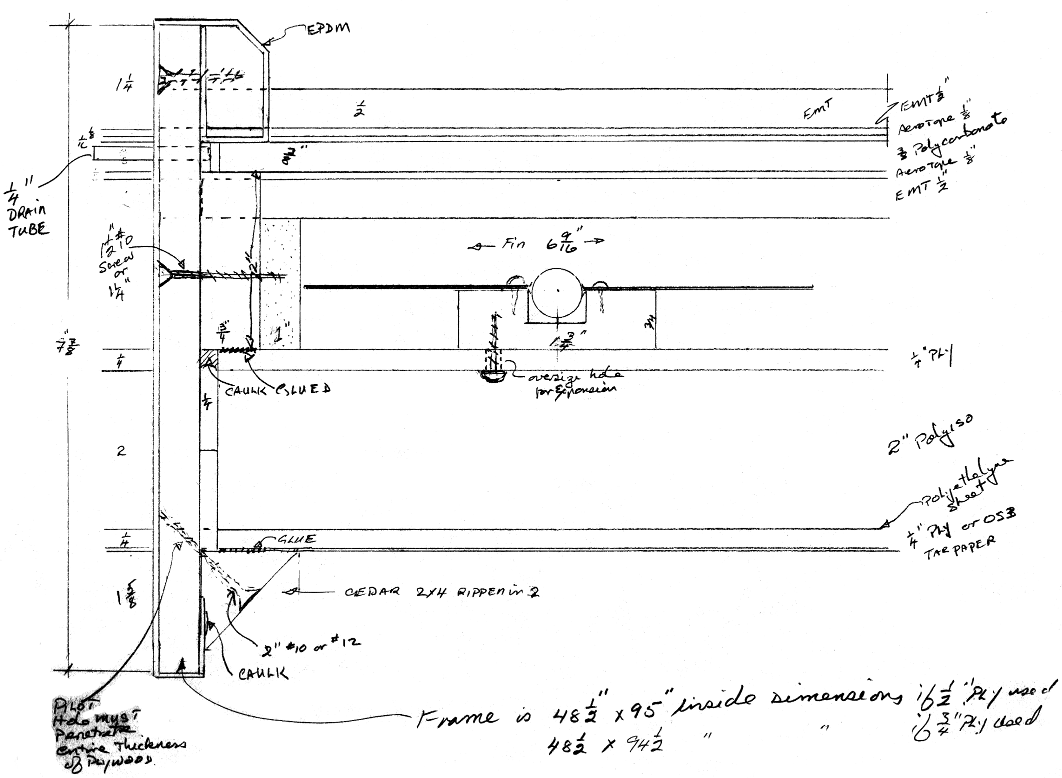


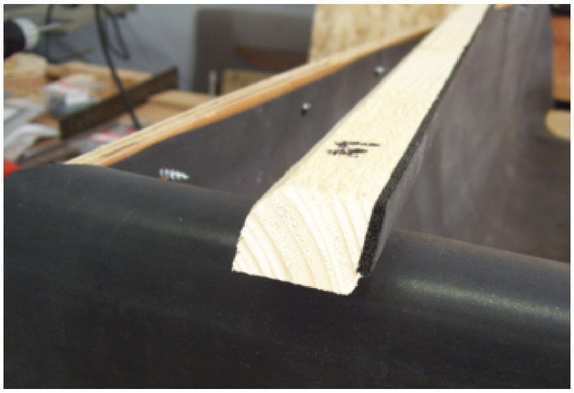


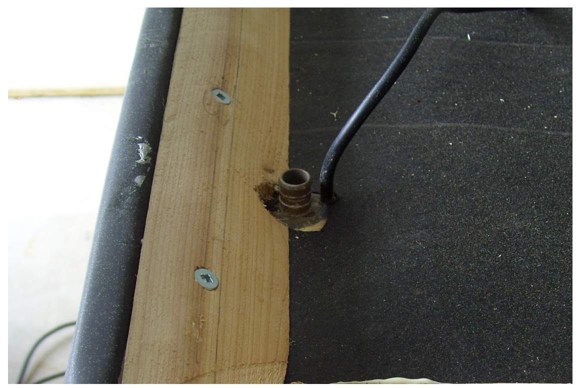
Strips of 3/4 inch thick spruce formed a perimeter border to which the

1/4 inch ply was glued and screwed. The stressed skin panel via the strips was glued and screwed to the 1/2 inch ply frame making it strong and rigid. This spruce also provided the perimeter seat on which the polycarbonate sheet sat (see section drawing).

To waterproof the back I used a sheet of 4 mil polyethylene between the polyiso insulation and the OSB. Finally I used black tar paper on the outside of the OSB. Final perimeter strips of cedar glued to the OSB joined it to the 1/2 inch plywood frame and clamped the EPDM rubber sheet which covered the outside (see drawing).





The collector temperature sensor was clamped on the fin close to the pipe at the output end of the collector.

Not wanting to deal with constructing oversize headers and a little scared off by reading about uneven flow in parallel flow collectors, I opted for a serpentine arrangement of seven pipes. Since the top of a collector is the hottest part due to air convection, I figured that the cold water going into the collector should do so at the top (also not having to worry about getting good drain back). This would hopefully have the effect of reducing the temperature gradient from top to bottom of the collector thus decreasing heat losses and hopefully slightly improving efficiency.

I also wanted to make my own fins using a home made press. I decided to press each fin so that it covered half the pipe and to make the fins no longer than 1 foot with a small gap so as to allow for the differential expansion. The aluminum flashing I was able to obtain was 0.022 inch thick. I made a press which worked quite well after replacing the initial hinges that were too light, for heavier ones. (see photo)

Just before I was about to put the collector up I was a bit shocked to see condensation starting to form on the inside of the glazing. I blew some air in with my compressor and found it fairly easy to dissipate. I decided that the wood used was not dry enough and later realized that the polyiso insulation may have been a bit wet too since it had been stored outside in the vendors yard for a couple of years. I installed eight vents, four in the bottom and four on the top of the collector. Aluminum tubing of 5/16 inch OD bent in a half a circle so the open end faced down glued into the holes along the top of the collector served as the vents. I glued them into the holes with Polyurethane glue. The bottom vents were simply 5/16 inch holes left open since they faced down. After a couple of weeks of baking in the sun with the vents open the condensation problem went away. I read that some professional units come with vents as well although not of the type I used.

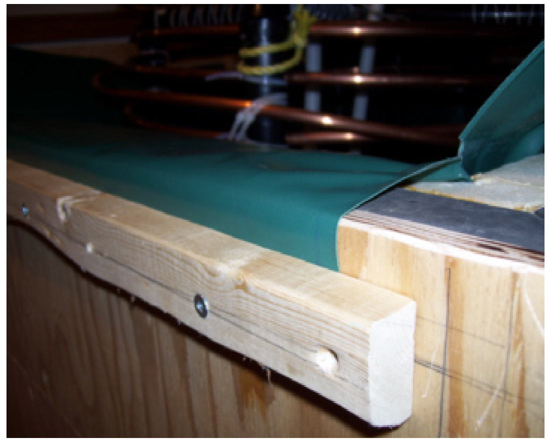
I bought some of the selective black paint and did a simple stagnation temperature test. My results were disappointing when comparing it to regular BBQ paint. There was very little difference if any in the stagnation temperature of the two test units.

The Tank:
I spent a lot of time considering options and designing the tank. I had training and have done some structural engineering in wood so was able to do an analysis and design of a tank relative to the bending and shear stresses that the plywood, beams and joints would experience. The space in our laundry room was limited and I figured that If I was going to the trouble of building a tank, it should hold as much water as

possible. Also I had hopes for adding more collectors and heating my office some time down the road. I could only spare 4 feet by 4 feet so decided to go up a bit and make the tank high enough to hold about 4'6" of water. The actual inside dimension of the tank is 40 x 40 x 53 inches of water which gives a capacity of 44 cubic feet or about 320 US gallons. I used 1/2 plywood for the outside reinforced internally with purpose built perimeter beams located at strategic heights inside the tank. The beams had heavy steel angles reinforcing the corners. All components were glued and screwed for maximum strength. Proper gluing allows for efficient use of wood as it is far stronger than just using screws or bolts. I used a good quality waterproof exterior grade glue. Even better would have been polyurethane glue. For insulation, I used 1 1/2 inch of polystyrene then 2 inches of polyiso all on the inside of the plywood. The insulation is cut to fit around the beams. The beams were 2.5 inches deep which left 1 inch of polyiso to cover them.

I initially considered and bought some EPDM rubber sheet to line the tank. Since the amount of corner fold increases a lot when the tank is higher than it is wide, I considered making my own seams. After looking at a few ways to make seams in EPDM rubber I chickened out and found a supplier who made a custom PVC liner for the tank. In the end it was cheaper or about the same price to have the PVC tank liner custom made (about $120 from www.tarprite.com) as use EPDM rubber with large folds.

The liner was simply placed in the tank. The top corners were slit down so that the green liner folds over the top edges of the tank and down the outside. Clamping strips of spruce hold it in place screwed on the outside. 1/8 inch thick HVAC foam EPDM Aerotape (purchased at Canadian Tire) was cut and forms a gasket between the top of the tank and the lid.

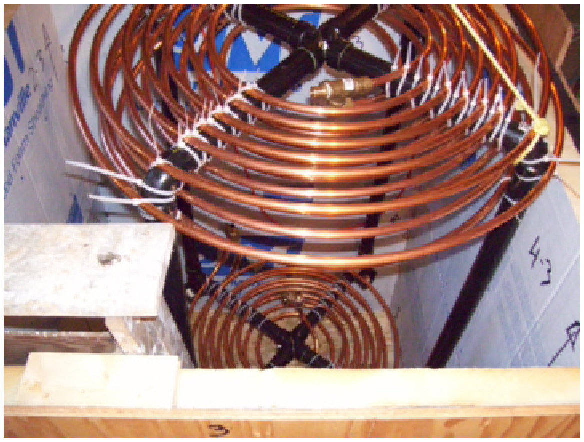
The lid is 1/2 ply with a 2x4 perimeter and again 1 1/2 inch of polystyrene and 2 inches of polyiso for insulation. The entire bottom side of the lid is covered with EPDM rubber sheet. A cut-out on one side holds a manifold and 6 holes allowing the pex pipes and temperature sensor wires into the tank. The lid can be lifted up without disturbing the pipes and wires. I used Recreational Vehicle roof sealant available from RV vendors to seal the EPDM joints that were made for the manifold cut-out. I also used this to seal the EPDM collector cover at the corners and I am impressed at how well it sticks to the EPDM rubber (Pro Flex RV™ Flexible Sealant from Geocel).

Underneath the tank is a pan made of EPDM rubber and has a drain tube in its corner. Should the tank ever leak I hope the pan will catch the water and we will be able to pump it out to a basement drain.

The heat exchangers:

Inside the tank there are two heat exchangers mounted on one frame. One to bring heat in from the solar collector and the other to preheat cold water going to my house. Each heat exchanger is made from 100 feet of 1/2 inch soft copper tube. In order to keep head loses to a minimum I split each tube in two and so the water splits and goes through two 50 foot long sections and rejoins again before exiting the tank in pex tubing. I did not know how to design a heat exchanger so I cheated a bit and found a reputable Solar energy vendor on the web who said how many square feet of copper pipe they used for their heat exchanger. I used a bit more than they did so I figured I was safe. I used an 1 1/4 inch ABS tubing to make a frame to hold the heat exchanger coils.



I am happy with the job the bottom heat exchanger does working with the collector as it has a small flow, but less so with the heat exchanger that pre-heats the domestic hot water. I think Gary's idea of using a long enough pipe to hold about 12 gallons of water inside the tank is brilliant. And I may try to modify my top heat exchanger by adding some PEX tubing to hold more water. However I actually found the 100 feet of 1/2 inch copper about the same price or cheaper here that the 300 feet of plastic pipe he used and it takes up a lot less room inside the tank. However it does not seem to work as well. I am also toying with the idea of using an insulated tank of 6 gallons outside the main tank and letting the water thermo siphon up into this tank to be available on demand.

Mounting on the roof:

Special racks were made to hold the collector (see photo). The bottom of the rack is about 10 inches above the roof to allow for some snow to accumulate without blocking the front of the collector. The collector is bolted to 8 “feet” for each collector. The feet are made of 2x4s ripped into 1 5/8 x 1 1/2 pieces that are lag bolted down through the shingles and roof sheathing and into the trusses (see photo). I injected Silicone caulk into each hole before screwing in the 5/16 by 4 inch lag bolts. I have not had a leak over the last winter. Finding the trusses from outside was a trick. I used an acoustic stud finder to help. First though I stood on the roof and shifted my weight from one leg to the other. I could tell from the way the roof surface gave way approximately where the truss was. I then put masking tape over the shingles where I thought the truss was and used the stud finder to fine tune the location of the truss (not easy since the tool is not really made for this).

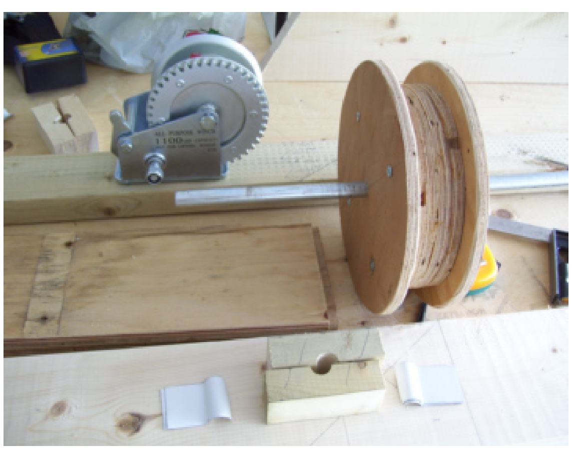
Pump, plumbing and controller:
Other than the copper pipe in the collector and heat exchanger all the plumbing is Pex. 3/4 inch pex for the main arteries and 1/2 pex into the collector. I bought a locally available Bell and Gossett (NRF25) 3 speed hot water for heating circulating pump for about $115. Two isolation valves were added one above and the other below the pump to allow its easy removal without draining the system. I put in three ball valves coming from the top heat exchanger that allows me to entirely bypass the solar hot water storage tank and revert back to a direct input into my electric hot water tank should a maintenance operation require that. Since it was going to be a closed circuit system I also bought a 25 KG pail of propylene glycol with corrosion inhibitors (Vedra Industries Toronto shop.glycol.ca about $95). Also had to add a standard Hot water heating type expansion tank ($60) and a safety release valve ($12). All the pex brass fittings and stainless steel clamps can add quite a bit to the price of the system so buy them in the largest quantity you can. The pex pipe is covered with the insulating jackets that are readily available at plumbing stores.

I ran the system on pure water for a month. I had to add a check valve in the pump since I was loosing heat from a thermo-siphon action at night when the collector was much cooler than the tank. The check valve stopped working after a few weeks. I drained the system to add the glycol mix and found the water a rusty color. I cleaned the check valve.(so far it has worked well). Then I measured the volume of water that drained, mixed half of that volume of glycol with the same volume of distilled water from my dehumidifier and put it in a bucket. I connected a submersible pump to the bottom of the solar systems plumbing with a hose, put the submersible pump into the bucket of glycol/water mix and filled the system till it flowed out the Air trap at the top of the collector.

The air trap is just a tee mounted at the highest point of the plumbing with a straight vertical pipe and two 90 degree elbows. Any air in the system bubbles up into the straight pipe and stops circulating back to the pump.

I bought a SHEM32 controller from Solar Heat Exchange Manufacturing (www.solarheatexchangemanufacturing.com/) and it seems to do a good job. Most electronic items can benefit from a good power bar so I plug the controller into one that has a light indicating that the protection circuitry is still working.

Lifting the collector in place:
I bought a 1100 lb hand winch and mounted it on 2x6's and made a pulley that the winch strap went over. The pulley was not turned on a lathe. Simply cutting the discs out with a jig saw was enough precision for the job. This system was screwed temporarily to the collector support and was used to hoist the collector (it weighs 190 lbs) into place.



Drain back Versus Closed Glycol system:
My system runs at the same pressure or only slightly above what a simple drain back system would of the same height. It is filled from below till the fluid flows out the top overflow. The overflow is then closed. A heat exchanger and expansion tank is used as is a safety relief valve. The pump must have a check value as well to prevent thermo siphoning at night. While this is more complicated, there are some advantages. The pump does not have to be anywhere as big or costly to overcome the initial head of a drain back system. I could use a serpentine arrangement for the collector pipes and not have to deal with oversize headers. I did not have to worry about keeping the lines sloping properly for effective drain back – this would have been quite a challenge through the attic. The glycol has corrosion inhibitors which are kind to the metallic plumbing and pump parts. However I will have to monitor PH levels and replace the glycol every 2 years or so.

Performance:
The system has been running about a month now (mid July to mid August) and on the best day I got a 7 degree F increase on the almost 3000 lbs of water or over 20,000 BTU capture with one collector. After that test I found that even running the pump at the lowest of the 3 speeds may not have been optimal however. I therefore used one of the two isolation values to throttle the flow considerably and seemed to get higher temperatures coming out of the collector. Since the temperature of the water leaving the heat exchanger going back to the collector was close to the temperature of the tank water I figured that it was not too fast. So this slower flow might improve the heat yield of the system.

Since the collector is vertical and my house faces about 20 degrees west of south it does not start to get sun until 11:00-12:00 am (daylight saving time). The tank is really meant to have a least three collectors – the other two which I am now building. The vertical orientation of the collector is not optimal (I am around 45 degrees latitude) but is used to avoid having to clean the snow off in wintertime (3-4 of 12 months). I might use an angle 10 degrees back from vertical for the next two collectors as Gary has suggested or maybe 15 degrees.

Cost/Benefit:
I have made some false starts most of them on the drawing board. I have a computer folder full of dozens of web sites that have furnished me with material and performance specifications for polycarbonate plastic, wood, copper, insulation, glues, selective surfaces etc. It has taken me down many roads of interest looking at things like the solar spectrum and phase change materials and the promise they hold. Its been a great trip and it's not over yet. So it has cost me lots of time but also given me lots of enjoyment. Of course it's for a good cause too – renewable energy is the way to go. When I get the next two collectors up I plan to have an open house and invite many people I have talked to on our island who have shown interest. Maybe some of them will take up the cause.

I have spent about $4,000 on materials. Bear in mind that this cost includes most of the materials for 5 collectors only 3 of which are built or under construction and a larger tank. Its been a great experience and I consider it money well spent! The system is not instrumented at present to the point where I can calculate energy savings so I will look at my power bill over a year period and see what the difference is.

Reference to Gary's site:
Please see www.builditsolar.com for the $1000 domestic hot water system that I compare my system to in the text. Many other peoples experiences are documented there as well as tools to help you design and build your own system.

My contact:
I would be happy to answer any questions about my experience. My email is wre9182736@yahoo.ca