SOLAR AIR HEATER

11/01/2015

INTRODUCTION

Here is our solar air heater. The panel is a horizontally-oriented, 4 ft. x 8 ft., ‘down and back’ 2-layer screen design, mounted in the vertical plane (90 degrees tilt). The collector stands 23 inches out from the S/SE wall of our out-building on an angle iron mount, facing approximately 160 degrees azimuth.

I used the excellent Sustainable by Design Overhang Design Tool to fine-tune panel location (link on Build It Solar). The hip-roof has wide 35 inch overhangs, only 7 ½ feet above ground level. The offset mount positions the panel out 5 inches from the edge of the overhang, with the glazing directly under the fascia. The panel enjoys full solar exposure during winter. Around the equinoxes, the overhang shades the panel only in late afternoon, when the sun angle is nearly oblique. As the sun path moves higher the panel is shaded earlier, until, at summer solstice, the panel is in full shade by solar noon.

The low-profile installation preserves the unobstructed view out the windows on the south side. The wide-angle photo was taken at solar noon on Sept. 26. The other two shots were taken 2 hours earlier, with the sun directly in front of the collector. As you can see, building was not consciously designed with passive solar in mind. The south windows are mostly shaded even in mid-winter.

The panel frame is built from two stacked layers of 25 ga. stud track, with a plywood back plate and SunTuf corrugated polycarbonate glazing. The air vents go through the back, in the upper and lower left corners. Two flexible, insulated 6-inch ducts carry the air up the outside wall, through the soffit, and over the brick wall into the back area of the building. Once inside, the heated air is ducted into the front room (far left window in wide-angle photo), driven by a 410 CFM centrifugal fan. An air filter box in the return duct holds a 14 x 14 pleated-paper air filter. The fan is controlled by a 24 V relay, wired in series with one of two (switch-selectable) snap discs inside the panel, and a bimetallic thermostat located in the front room.

The only part of the building that is finished inside is a 22 ft. square room in the front. We use this area for office space, and this is where we direct the heated air. The resulting air-flow path is far from ideal - too long and too many turns, but it was the least disruptive to the structure. I didn’t want to cut holes through the brick wall.

I borrowed liberally from ideas and designs featured on Simply Solar and Build It Solar (thank you all).

WALL MOUNT

The mount establishes two vertical ‘rails’, 72 inches apart, for attaching the panel. I fabricated the mount from some old range fence corner-bracing that had been piled in the corner of the yard for years. The material is 2-inch angle iron, overkill-heavy, but it’s galvanized and straight; also the price was right – free. The mount is bolted to the brick wall using 5/16 x 1 ½ inch Red Head masonry sleeve anchors. The lateral triangular braces are fabricated from 1-inch EMT, with the ends flattened, drilled, and bent to the correct angle.

One limitation with this type of mount is that it doesn't provide a continuous attaching surface for the panel. The plywood back plate is what is bolted to the angle iron mount, and what gives the panel the stiffness to bridge the span. The top and bottom bolts on each rail also pass through the back flange of the stud track.

PANEL FRAME CONSTRUCTION

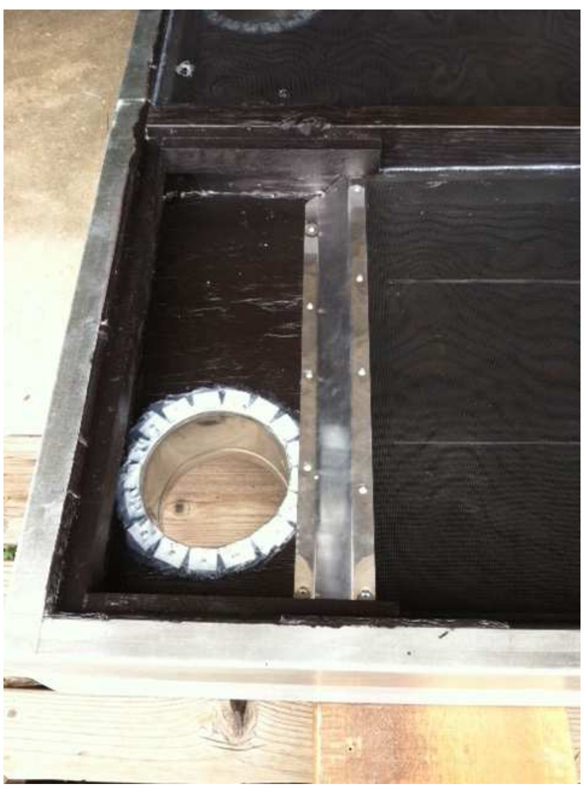
The panel frame is made from 25 ga. metal stud track, built in two layers, 3 5/8 inch + 2½ inch. I figured I needed 6 inch depth for the slanted screen absorbers. The ends of the stud track pieces are notched and folded over 90 degrees, and the corners joined with pop rivets. I fit the 4x8 plywood sheet into the back frame before riveting the last two corners. The plywood is held in place with some home-made angle brackets screwed into the plywood and riveted to the stud track.

Once the plywood back plate was tight in the back frame, I set it in place on the mount and drilled holes through plywood and the angle iron. I hammered 5/16 in. T-nuts into the front face of the plywood and temporarily ran 5/16 x 1 inch bolts through the frame from the back and into the T-nuts. The top and bottom bolts in each row also pass through the stud track. The finished assembly is quite rigid. Once I knew everything fit, I removed the back frame from the mount to build the rest of the panel. I attached the front stud track frame to the back frame with small screws all the way around, adding a bead of silicone seal between the two sections. I also sealed the corners and all the rivets.

I would have much rather just used a single piece of 6-inch stud track, but I couldn't find it at the local building supply stores. The down side of the two-level frame is that it leaves a flange running down the middle, right where you need to attach the screens. Also the flange makes it difficult to insulate inside the frame.

PANEL INTERIOR CONSTRUCTON

I glued 2x4 blocks into the stud-track channels to provide anchor points for the screens. The spaces between the blocks are filled in with pieces of 1-inch + 1 ½-inch polyiso. The dividing wall between the upper and lower absorber sections is a 2x8 board, ripped to match the width of the panel. The divider is screwed to the back plate and to a 2x4 block on one end. The other end stops 12 inches short to leave room for the turn-around plenum. I insulated the back with 1 inch polyiso. The following series of pictures show the internal layout – two absorber sections, screens, vent details, baffle plate, and end plenum. The black screen doesn't show up that well, but all the screens are there in the last photo:



The 2x4 blocks fitted into the stud track were sort of a compromise; they created too many thermal bridging paths to the outside. Reconsidering, it may have been better to first insulate all around with 1 in. polyiso, and then fit an inner frame made from 1x4's for the screens.

The screens sit on angled 1x2 boards, screwed to the mounting blocks and to the center divider wall. The absorbers are simple 1x2 frames with screen stapled to both sides. I couldn't find charcoal aluminum screen except in big rolls, so I used bright aluminum screen, spray-painted flat black. I left the painted screens outside to bake in the sun for a couple days before putting them into the panel. I thought about using charcoal fiberglass screen, but I wasn't sure how it would hold up. Fiberglass may be OK; the SunTuf glazing is supposed to filter out UV anyway.

The intake and output vents are located on the back - intake at lower-left, behind the baffle plate, and output at upper left. Short 6-inch duct sections have folded-over tabs, screwed to small pieces of 3/8 inch plywood. The plywood pieces are glued to the insulation board and screwed through the insulation into the plywood back plate. An aluminum baffle plate baffle directs the incoming air onto the top surface of the lower screen absorber. The air comes out (mostly) under the screen at the far end, into the turn-around plenum. The plenum is just an open area with a folded-over double layer of screen 1 inch beneath the glazing. The plenum screen is stapled to around the outside of the panel frame and to the top of the lower screen frame. I thought about covering the plenum with a piece of painted-black aluminum flashing instead of screen; I'm still not sure what would work best here. After making the U-turn, the air hits the top surface of the upper screen, finally coming out underneath at the outlet vent in the upper left corner. Short sheet-metal ramps guide the air onto the leading edge of the absorbers.

Two snap-discs are mounted to a hand-bent aluminum bracket near the outlet vent. The two snap-discs are 90/110 and 110/120, with an inside selector switch (explained below in ‘Controls’ section). The wiring run through the back plate into an outdoor plastic J-box attached to the back of the panel. I forgot to put in the snap-discs until after the glazing was installed – dumb mistake. I had to reach in through the output vent to screw the bracket to one of the 2x4 blocks in the side wall. The wiring to the inside is not run yet in the photo, but it comes out of the J-box and follows the mount structure, then goes inside via wall enclosure.

GLAZING

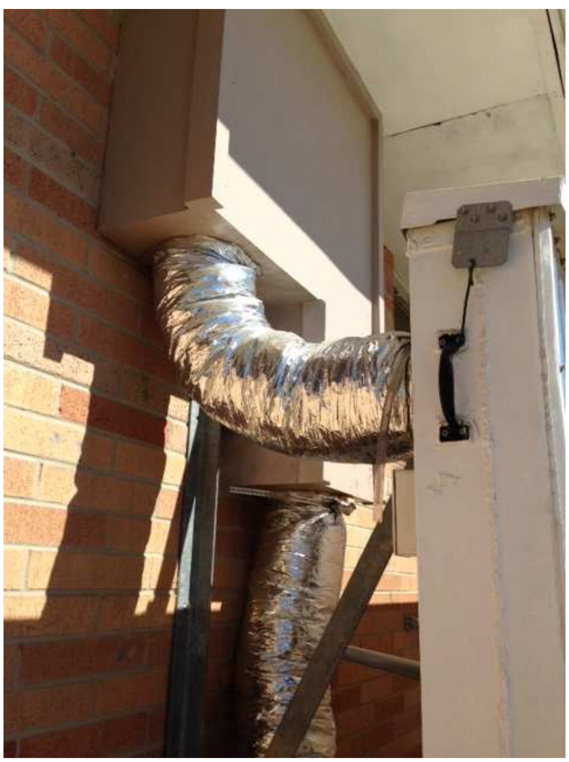
The glazing material is Palram ‘Suntuf’ polycarbonate. I wanted to use twin-wall, which I thought would perform better and be easier to work with, but it was not available locally at Home Depot or Lowes. (Note - I decided early in the project to only use readily available materials. I tried to purchase everything from the nearby Home Depot 1 mile away.) When I asked about the twin-wall, the crew at Home Depot didn’t seem to know anything about it, so I went with the Suntuf instead. I was at the store a couple months later, and there was a bin full of 3/8 inch twin-wall, right next to the Suntuf! Maybe my story about building a solar air heater inspired them. I plan to try the twin-wall next time.

The Suntuf is installed with the corrugations running vertically. I cut each 2 ft. x 8 ft. piece in half, using a circular saw with a fine-pitch plywood blade. I glued the foam closure strips to the top and bottom stud tracks and the center wall with silicone. To attach the glazing, I drilled clearance holes in the Suntuf, then marked and drilled the closure strips and stud track with small pilot holes. I used the recommended wood screws with rubber washers to screw the glazing through the foam strips and stud track frame into the wood blocks below, with a generous bead of silicone between the Suntuf and the foam strips. Some of the screws just thread into the stud track, but they held OK. The Suntuf panels overlap by one corrugation; I sealed these joints with clear silicone as I set on each new piece. On the left and right sides, the Suntuf overlaps the frame at a 'peak'. I ripped some 1x2 PVC trim into ¾ x ¾ strips, and glued and screwed the Suntuf through the trim strips and into the frame.

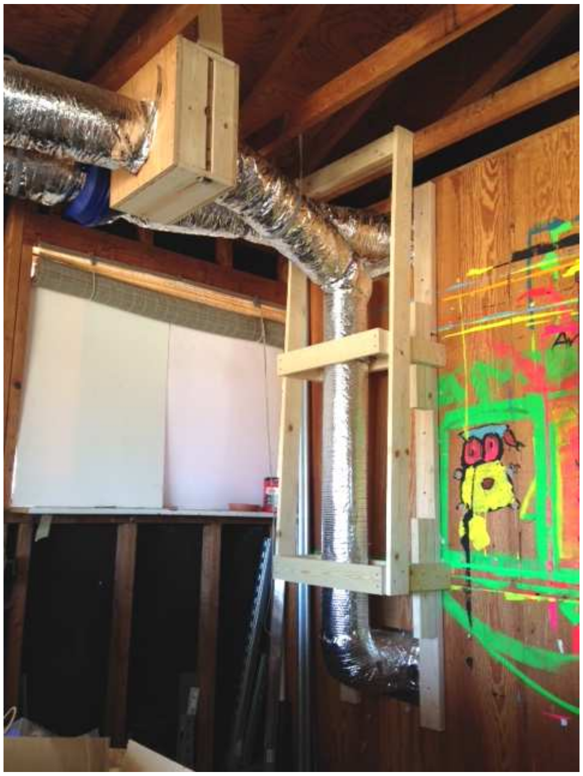
I haven't seen any leaks, but just for extra insurance, I made a sloped 'rain-hat' from a piece of 1x8 covered with aluminum flashing. The cover is visible in the side view photo in the Introduction section.

AIR DUCTS

The 6-inch air ducts run up the outside wall, through the soffit, and over the bricks. The brick facing end at the soffit level; above that there is only some ½ inch thick 1950's 'insulation board' (I use the term loosely), which is visible inside the back room. The rafters are 14 inches above the soffit, so I cut two holes through the insulation board and fit a plywood 'bulkhead plate', with 6-inch duct-splice sections, to go through the openings. On the outside wall behind the heater panel, I built a plywood enclosure for the insulated ducts. I attached this housing to the brick wall with Tapcon brand 2 ¾ inch masonry screws. Insulated ducts run from the bulkhead plate on top to two more duct splices at the bottom of the outside enclosure. Two short, easily replaceable sections of insulated flex connect the duct enclosure to the heater panel. These are the only outside ducts you see in the finished installation. I cut a new soffit piece to fit around the outside enclosure, finished it off with 1x2 molding, and painted everything. Here are pictures of the bulkhead plate and the outside enclosure:



Inside the back room, more flex sections take the air from the bulkhead plate to the Suncourt TF106 6-inch, 410 CFM centrifugal fan on the output side, and to a wood air filter box on the intake side. The air filter box holds a standard 14 x 14 pleated paper air filter, with a hinged door covering the access slot (door added after the photos). More flex duct carries the heated air from the fan to the upper register box on the inside wall, and return air from the lower register box to the filter box. The duct that runs up the wall is 6 inch rigid, wrapped in insulation blanket, with the whole thing surrounded by some 2x4 'crash bars'. Hopefully this will protect the ductwork from heavy items stacked nearby. In case you are wondering, a graphic artist once worked here. The little character on the wall is watching us work. The following pictures show the internal duct paths and the air box:

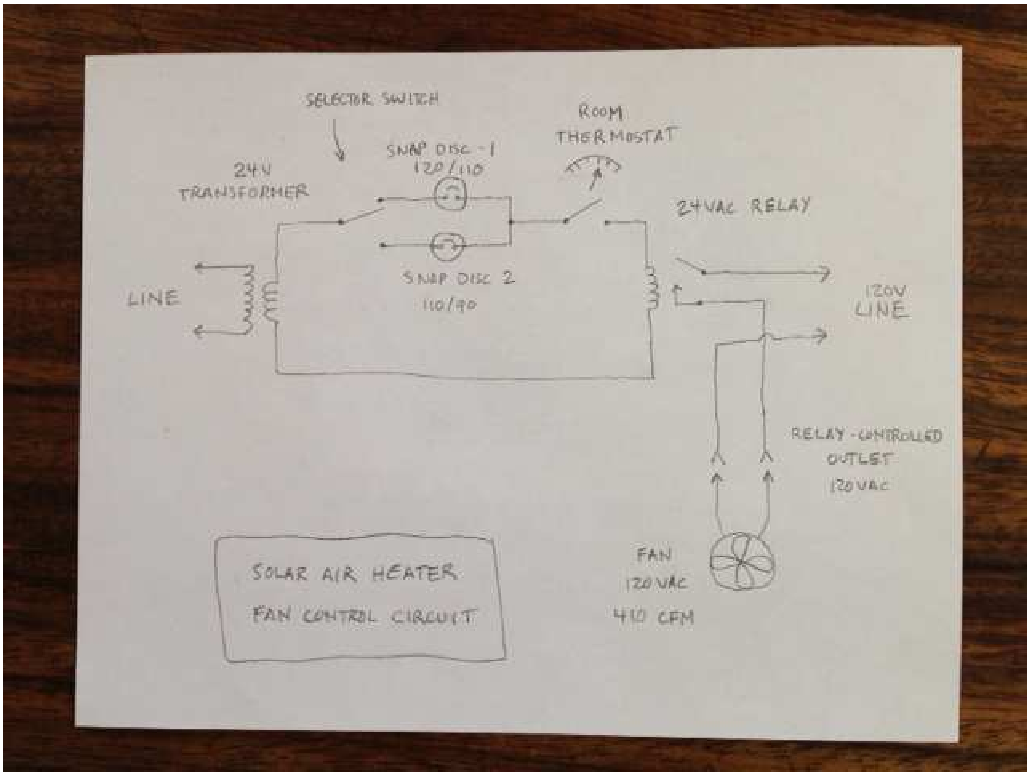


Total duct length adds up to 32 feet, with 12 ft. on the hot air side, and 20 ft. on the return side. In spite of the long duct runs, the 410 CFM fan runs quiet and moves a good stream of air into the room. I don't have any measurements, and it hasn't gotten cold enough yet this year to run the panel more than briefly, but I can feel plenty of warm air coming out during some brief tests.

NOTE: In the two weeks since this was written, it has cooled off here considerably. We are using the heater quite a bit now. On sunny days, it runs almost continuously until early afternoon. The panel puts out a lot of heat; at times it warms the room up to where the room thermostat turns off the fan. Sometimes we even open a window while it is running, an extravagance we could never indulge with the gas-fired furnace. If there are broken clouds, the snap-disc can cycle on and off, depending on cloud cover. This happens more in the afternoon, when the sun hits the panel at a greater angle. We are still experimenting with thermostat setting and with the two snap-disc ranges, but overall, the solar heater has made a big difference. We haven't run the gas furnace at all (yet). It will be interesting to sees how the solar heater does this winter.

CONTROL SYSTEM

I didn't want to run 120V into the panel, or outside at all, so I built a low-voltage control circuit to control the fan. The snap disc, in tandem with a bimetallic room thermostat, controls a 24V relay to energize the fan. I originally installed a 90/110 degree snap disc, but then I wasn't sure if the output air would feel too cool at snap-disc cut-off. The next size up is 110/120, which probably lowers overall efficiency by leaving more heat in the panel. I wasn't sure which was best, so I finally made a new bracket to hold two snap discs and made them switch selectable. We are running the 110/120 at this point. If the panel was heating a basement, garage or workshop, I would probably go with the 90/110. Anyway, we have both ranges available, selectable with an inside toggle switch, so we can experiment. Here is the schematic (Note: all 120V receptacles are grounded; ground connections omitted from drawing for simplicity):


SELECTOR SWITCH
ROOM THERMOSTAT
SNAP DISC - 1 120/110
24V TRANSFORMER
24VAC RELAY
SNAP DISC 2 110/90
LINE
120V LINE
RELAY - CONTROLLED OUTLET 120VAC
SOLAR AIR HEATER
FAN CONTROL CIRCUIT
FAN 120VAC 410 CFM


SNAP-DISC SELECTOR
120 / 110
110 / 90

When the control loop closes, the relay is energized, feeding 120VAC to a dedicated 120V receptacle for the fan. The room thermostat is a re-cycled 1970's electric baseboard heater thermostat. It's crude, but it's perfect for the solar heater, since it consumes no power; just open or closed, depending on where you set the dial. Calibration is not great, although repeatability is fine. The thermostat has an OFF position to disable the system during summer months. I purchased the Suncourt centrifugal fan, 24V transformer, and 24V SPST relay from Home Depot, and ordered the White-Rogers snap discs on line from SupplyHouse.com. The room thermostat came from the junk box. The following photo shows the grilles where the air feeds into the front room:

WHAT'S NEXT?

One enhancement I would like to try is a reflector in front of the panel. I see another builder on SimplySolar (a fellow resident of the Denver, CO area no less) reported good results with a space blanket reflector.

Another idea would be to power the heater fan from our home-built 540W battery-based PV system. The PV just powers some PC's in the office, but I think it will support the heater fan too (109 W @ 0.89 power factor). I just need to wire another outlet from the PV / Utility transfer switch. Here is our PV array:

I thought of different and better ways to do almost everything during construction. I also had to change plans many times while standing in the aisle at Home Depot, deciding which ‘almost what I wanted’ item would work best. More hot-air panels - of course! This business is habit-forming, and a lot of fun too. I am already sketching out a horizontal tube-type (downspout) design using some slightly squished 3-inch corrugated aluminum ducts in a 3 5/8 inch stud-track frame with twin-wall glazing. I want to try routing the air through the end wall instead of the back, with the goal of smoothing air flow inside the panel. I also want to incorporate continuous insulation and explore some ‘ultralight’ construction techniques to reduce thermal mass and bridging, and speed up response time. I want to design a ‘clean’ sealed air flow path, with as little wood as possible inside the panel and no painted surfaces contacting the heated air stream. Our panel put out a slight smell initially, which seems to be decreasing by the day, but I don’t want to gas anybody. I have some ideas for a staked, low-impact ground mount (I have rock-hard clay a few inches below the surface – no fun to dig). The new ‘zero-pass’ projects I see on SimplySolar look interesting. I am always looking for ways to streamline the assembly process and minimize hardware (our panel took a long time). We will see.