# RE Lab Solar Heater

# Operation and Assembly Manual

**Jacob Apodaca - Test Engineer**

**Brendan Frazier - Project and Logistics Manager**

**Tyler Hedgecock – CAD Engineer**

**Joseph Meza – Financial Manager**

**Calvin Schenkenberger – Manufacturing Engineer**

**Summer 2025 - Fall 2025**

NORTHERN ARIZONA UNIVERSITY

**Project Sponsor:** Professor Carson Pete

## Introduction

This manual outlines the cost of materials, installation, assembly, and procedure of operating the system. It also includes how to troubleshoot any issues that the system may encounter such as fans blowing cold air, the system not turning on, and a lack of airflow.

## Assembly

### Bill of Materials

To assemble the system, it is easiest to divide the process into subsystems. As shown in the table below, these are Mounting, Roofing, Electrical, Ducting, and Panels. Proper roofing and panels are assumed for this project, but the materials and budget required for new ones are provided anyway for convenience.

*Table 1: BOM*

| Bill of Materials | | | | | |
|---|---|---|---|---|---|
| Item | Category | Description | Unit Cost | Quanti | Cost |
| 14 Gauge Unistrut | Materials: Mounting | 10ft section for mounting frame | $41.00 | 3 | $123.00 |
| 1/2" by 5" Lag Screws | Materials: Mounting | Mounting unistrut to roof | $1.76 | 10 | $17.60 |
| Gold Galv Sqr Washer | Materials: Mounting | Mounting unistrut to roof | $2.12 | 18 | $38.16 |
| Gold Galv 2-hole L Bracket | Materials: Mounting | Mounting panels to unistrut | $3.44 | 8 | $27.52 |
| 1/2" Nylon Cone Nuts | Materials: Mounting | Connecting unistrut or L brackets | $1.31 | 24 | $31.44 |
| 1/2" Locking Washer | Materials: Mounting | Safety measure for mounting | $0.47 | 30 | $14.10 |
| 1/2" Washer | Materials: Mounting | Spacers and securing | $0.45 | 30 | $13.50 |
| 1/2" x 5/16" galv bolt | Materials: Mounting | Mounting L bracket to unistrut | $0.62 | 8 | $4.96 |
| 1/2 x 1-1/2 galv bolt | Materials: Mounting | Mounting panel to L bracket | $1.01 | 8 | $8.08 |
| 1/2 x 13 tpi galv bolt | Materials: Mounting | Matched to bolt size and tpi | $0.52 | 8 | $4.16 |
| Pivoting Strut Brkt | Materials: Mounting | For angling rear panel | $55.97 | 2 | $111.94 |
| | | | | | |
| GAF Roll Roofing | Materials: Roofing | New roof material | $133.40 | 9 | $1,200.60 |
| Drip Edge Flashsing | Materials: Roofing | Prevent water leakage at roof edge | $8.73 | 2 | $17.46 |
| Roofing Nails | Materials: Roofing | Secure DE flashing (50 pk) | $6.10 | 1 | $6.10 |
| SKYSHALO Pipe Flashing | Materials: Roofing | Sealing location of ducts | $39.87 | 4 | $159.48 |
| Henry 900 | Materials: Roofing | Waterproofing screws and flashing | $12.01 | 2 | $24.02 |
| | | | | | |
| Sunon 12V DC Fan | Materials: Electrical | Fans used to transport heated air | $79.51 | 2 | $159.02 |
| Weewooday Thermostat | Materials: Electrical | Engage or disengage the system | $6.99 | 1 | $6.99 |
| Flexible Conduit | Materials: Electrical | Route wiring in attic | $27.00 | 1 | $27.00 |
| EMT Conduit | Materials: Electrical | Route wiring in main room | $6.83 | 1 | $6.83 |
| Junction Box | Materials: Electrical | Storage for electrical components | $3.73 | 2 | $7.46 |
| 10 AWG PV Wire | Materials: Electrical | Wires exposed to outdoors | $0.60 | 30 | $18.00 |
| 16 AWG Wire | Materials: Electrical | Wires internal of the building | $17.98 | 1 | $17.98 |
| 5A Fuse | Materials: Electrical | Over current protection | $1.40 | 1 | $1.40 |
| Fuse Housing | Materials: Electrical | Holds fuse in circuit | $5.99 | 1 | $5.99 |
| Single Pole Togle Switch | Materials: Electrical | Used as master switch for system | $4.40 | 1 | $4.40 |

*Table 2: BOM*

| Bill of Materials | | | | | |
|---|---|---|---|---|---|
| Item | Category | Description | Unit Cost | Quanti | Cost |
| 8"x6"x6" Wye | Materials: Ducting | Splits air for main room | $17.98 | 1 | $17.98 |
| 8" 90 | Materials: Ducting | Used at inlets ducts | $9.98 | 10 | $99.80 |
| 6 inch 90 | Materials: Ducting | Used at angled panel to direct ducts | $8.68 | 2 | $17.36 |
| 8 x 6 adapter | Materials: Ducting | All transitions for attaching to panel | $14.28 | 4 | $57.12 |
| 6 inch duct | Materials: Ducting | Routes air to main room | $59.68 | 1 | $59.68 |
| 8 inch duct | Materials: Ducting | Routes air to front room | $67.98 | 1 | $67.98 |
| Duct Insulation | Materials: Ducting | Additional insulation energy retentior | $27.98 | 1 | $27.98 |
| 10 x 4 to 6 register box | Materials: Ducting | For vents in main and front room | $12.49 | 3 | $37.47 |
| 10 x 4 vent | Materials: Ducting | General purpose vents for dispersion | $13.98 | 3 | $41.94 |
| Duct Tape | Materials: Ducting | Duct connections and sealing | $13.98 | 1 | $13.98 |
| | | | | | |
| 4 x 8 White Polywall Panel | Materials: Panels | Replacing backing on panels | $28.42 | 2 | $56.84 |
| 1 x 4 x 8 R-6 | Materials: Panels | 1 inch thick insulation for panels | $36.02 | 3 | $108.06 |
| Nashua 324A Premium Foil | Materials: Panels | For reassembling panel interiors | $26.22 | 1 | $26.22 |
| 1/2 In 4 x 8 Polystyrene | Materials: Panels | 1/2 inch thick insulation for panels | $13.09 | 1 | $13.09 |
| | | | Total Budget | | $3,000 |
| | | | Total Cost | | $2,484.50 |
| | | | Remaining Budget | | $515.50 |

## Mounting System

### L-Bracket Installation

To make the solar air heaters compatible with the mounting system, 4 half inch holes in the frames of both solar air heaters are drilled. Half inch bolts are inserted into each hole from the inside to the outside with square washers on the inside. After reassembling the frames, the L-Brackets are attached onto each bolt for a total of eight L-Brackets to be able to then attach to the Unistrut. The bolts are attached to the L-Brackets using locking washers and nuts. The L-brackets are attached to the Unistrut using half inch bolts, nylon cone nuts, and locking washers.

### Cutting the Superstrut

The first step of installing the mounting system is cutting the Superstrut to the proper size. One length can be left intact, one needs to be cut at 4.5 feet and 5.5 feet, and the other needs 2 cuts at 2.3 feet and 6 cuts at 6 inches.

**Installing Roof Truss Shoulders**

The Superstrut will need to be installed on the roof with ½" lag screws in the roof trusses. Since the trusses are only 1.5” wide, installing shoulders is recommended to give the installers some room for error. Before installing the shoulders, drill a 5/16” hole through the roof from inside the attic adjacent to the north side of the southernmost truss ~6” down the eastern side from the apex of the roof. Mark the location of this hole on the roof, so you know where to begin predrilling holes in the next step. To install the shoulders, cut scrap 2x4 lumber into ten 1’ lengths. From inside the attic, using 4 screws per shoulder, screw the shoulders onto the north side of each top and bottom corners of the five southernmost roof trusses on the east side of the building. For clarity, the midpoints of each top and bottom shoulder should be ~98” apart, which is the approximate spacing required for the Superstrut on the roof. When installing shoulders, be sure that they are flush with the trusses because leaving gaps will reduce the strength with which the lag screws are attached.

**Predrilling for Lag Screws**

Starting with 5/16” hole that you marked earlier, redrill this hole 5” deep so the shoulder is also predrilled. Continuing north parallel to the ridge of the roof, predrill 4 more holes spaced 2 feet apart. To predrill the holes on the bottom row, extreme accuracy is needed. Since each panel varies slightly in size, start by measuring the length of the large panel. Add 1.5” to this length, and that is the spacing required between the top and bottom rows of predrilled holes for the large panel. In our case, since the panel is 97.5” long, this length was 99”. Starting at the southernmost hole, measure this length perpendicularly east from the line of holes and mark this location. Predrill a hole here, as well as one 2’ to the north. Using the same process for determining the hole spacing for the large panel, determine the spacing of the small angled panel. For us, this value was 97.5”. From the center hole in the top line of holes, measure this distance perpendicularly east from the line of holes. Predrill a hole at this location, as well as two more holes to the north of this hole so that the three are spaced 2’ apart in a line.

**Installing Superstrut**

Now that the holes are drilled, fill each hole with copious amounts of Henry 900. Place a circular flat washer centered on each hole, then place the 10’ length of Superstrut on the top row. Once the Superstrut is aligned with the pilot holes and circular washers, a square washer and locking washer are aligned with the same pilot hole. The lag screw is then fed through and drilled through the pilot hole that is filled with Henry 900. This process is repeated 5 times along the length of the top piece of Superstrut. The same process is followed for the lower pieces of Superstrut maintaining the variable spacing. The pivot brackets are installed at the northernmost points on the top and bottom pieces of Superstrut. To do this place two nylon cone nuts where they are approximately needed in the Superstrut channel and then placing the pivot bracket over top. A locking washer is placed over both mounting holes of the pivot bracket, and the nylon cone nuts are lined up with the mounting holes. A 0.5" bolt is is fed through the mounting hole and bolted into the nylon cone nut. This process is followed for both pivot brackets. The 2.3' sections of Superstrut are then mounted to the pivoting part of the brackets. This uses the same process of placing nylon cone nuts in the Superstrut channel and lined up with the pivoted section and bolted in a locking washer. This process is completed for both upper and lower pivot brackets.

**Installing Flat Solar Air Heater**

To mount the flat solar panel (located on the southernmost part of Superstrut) requires 4 of the 6" pieces of Superstrut to be installed 4' apart and installed using the same method as with the pivot brackets using the nylon cone nuts, locking washers, and 0.5" length bolt. The solar panel mounting L-brackets are then lined up with the center of the 6" pieces with a nylon cone nut in the center of the channel. The locking washer is placed on the L-bracket and the 0.5" bolt is fed through and secured to the nylon cone nut. This process is repeated for all 4 corners of the flat mounted solar panel.

**Installing Angled Solar Air Heater**

To mount the angled solar air heater, pivot brackets are used to achieve a 35° angle / tilt. The pivot brackets are attached to 2.3-foot Unistrut section that attach to the L-Brackets on the frame as mentioned before. This was done using half inch bolts, locking washers, and nuts. The pivot brackets are attached at the base to the superstrut frame using half inch bolts, locking washers, and nuts. The front (south end) of the angled solar panel is attached to the superstrut frame using half inch bolts, locking washers, and nylon cone nuts attached to the L-Brackets.

## Electrical

BEFORE WORKING WITH ANY WIRING OR ELECTRICAL PARTS TURN OFF SWITCHES IN FIGURES 5, 6, and 7.

**Conduit**

First ¾ inch rigid conduit was used to provide a pathway for the electrical wiring to travel through. This was connected to the load box using couplers, nipples, and an LB conduit body. This rigid conduit then connected to our first J-box which houses our thermostat and master switch. All of the rigid conduit is secured to the walls using one-hole straps. From there, the rigid conduit continued up and into the attic where it was attached to a new J-box using couplers and nipples. On the J-box in the attic 2 different lengths of ¾ inch flexible conduit was installed for ease of use and connected to run along the rafters using 1-hole straps.

**Wiring**

The electrical system starts at the load box in the RE Lab where we connect 16-gauge wires to 8-gauge wires from the solar panels battery supply to get our 12V power supply for our fans using wire nuts and mechanical lug connectors. From there we run wires through rigid metal conduit to the first J-box which has a thermostat and master switch housed inside using lever nuts. These wires then run up through rigid metal conduit into the attic into another J-box where they are connected to 10-gauge PV wires using wire nuts and are split off through flexible conduit to go to both fans on the roof where the 10-gauge PV wires are then connected to the fans which had 24 gauge wires and to increase the wire size we connected 16-gauge wires with butt-splicers and then connected the 16 and 10 gauge wires with mechanical lug connectors.

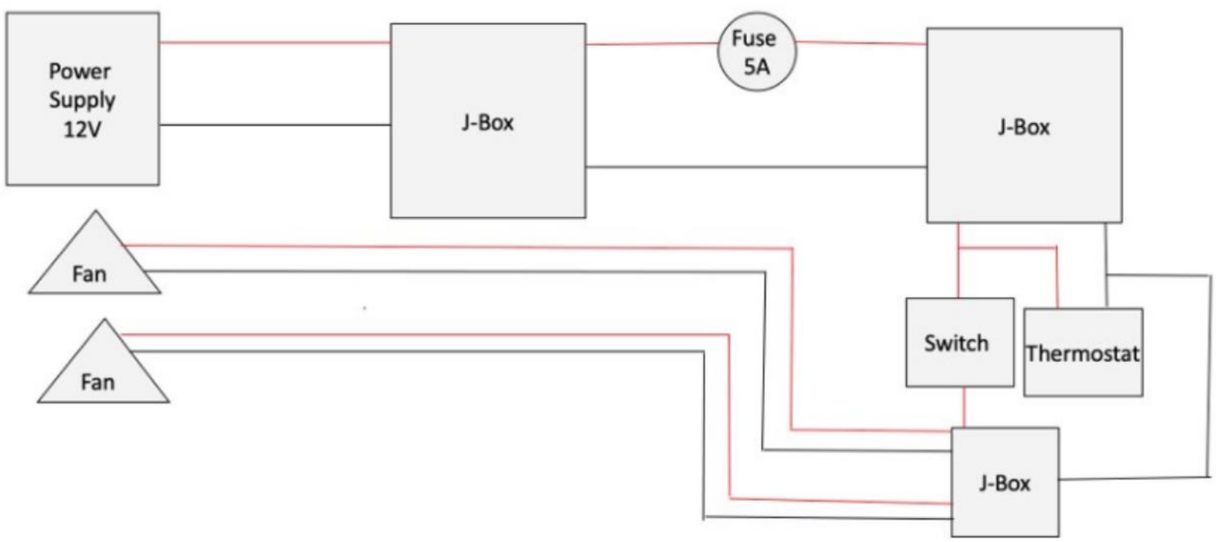


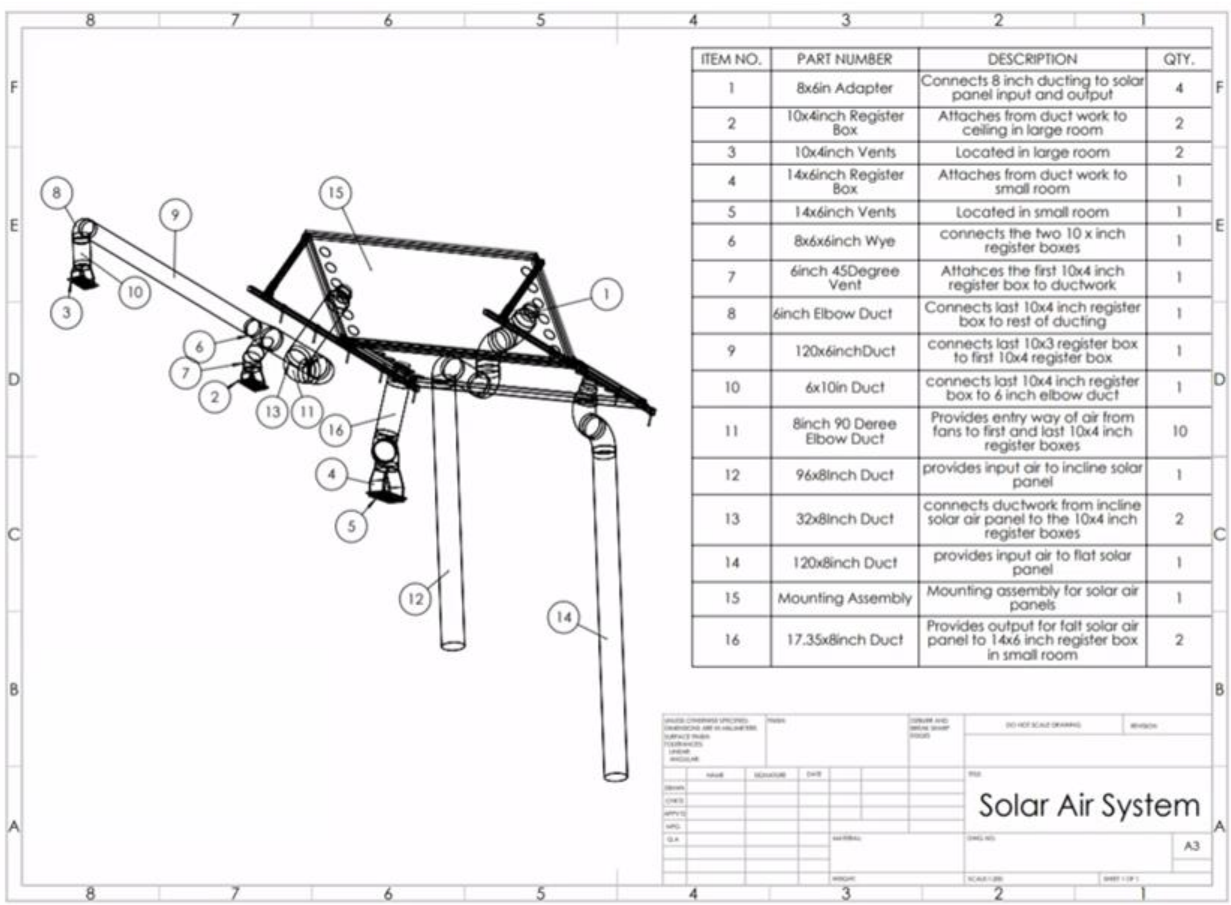

*Figure 1: Electrical Circuit Diagram*

## Ductwork

The duct system links the solar air collectors to the building and is divided into two main sections running through the Upper Half Backroom and the Upper Half Front Room, as shown in Figure 3. The key components include Solar Air Heater 1 and Solar Air Heater 2, each with its own dedicated inlet, outlet, and return airflow routes. Any of the nonflexible ducts are connected by HVAC sheet metal screws.

In the Upper Half Backroom, the inlet duct transitions through an 8" × 6" reducer and uses three R8 90° elbows to direct air into the system. Flexible R6 ducting attaches to two 10" × 4" to 6" register boxes, helping distribute warm air throughout the backroom. A 6" × 6" × 8" wye fitting merges the smaller duct branches into the main supply run. This layout ensures that heated air entering the collectors is evenly distributed before moving toward the outlet side. The backroom is integrated with Solar Air Heater 2, with its inlet also located within this space. In the Upper Half Front Room, the ducting follows a similar arrangement but incorporates larger fittings to support increased airflow. The inlet utilizes 8" × 6" reducers and R8 flexible duct, while a 14" × 6" to 8" register box transitions the flow into the distribution pathway. Additional R8 90° elbows navigate around tight sections of the room. The outlet ducts similarly use 8" × 6" transitions and 90° elbows before delivering heated air into the space.

Both Solar Air Heater 1 and Solar Air Heater 2 make use of R6 and R8 ducting, which allowed for easier installation, reduced vibration, and more flexible routing across both rooms.




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | 8x6in Adapter | Connects 8 inch ducting to solar panel input and output | 4 |
| 2 | 10x4inch Register Box | Attaches from duct work to ceiling in large room | 2 |
| 3 | 10x4inch Vents | Located in large room | 2 |
| 4 | 14x6inch Register Box | Attaches from duct work to small room | 1 |
| 5 | 14x6inch Vents | Located in small room | 1 |
| 6 | 8x6x6inch Wye | connects the two 10 x inch register boxes | 1 |
| 7 | 6inch 45Degree Vent | Attahces the first 10x4 inch register box to ductwork | 1 |
| 8 | 6inch Elbow Duct | Connects last 10x4 inch register box to rest of ducting | 1 |
| 9 | 120x6inchDuct | connects last 10x3 register box to first 10x4 register box | 1 |
| 10 | 6x10in Duct | connects last 10x4 inch register box to 6 inch elbow duct | 1 |
| 11 | 8inch 90 Deree Elbow Duct | Provides entry way of air from fans to first and last 10x4 inch register boxes | 10 |
| 12 | 96x8Inch Duct | provides input air to incline solar panel | 1 |
| 13 | 32x8Inch Duct | connects ductwork from incline solar air panel to the 10x4 inch register boxes | 2 |
| 14 | 120x8inch Duct | provides input air to flat solar panel | 1 |
| 15 | Mounting Assembly | Mounting assembly for solar air panels | 1 |
| 16 | 17.35x8inch Duct | Provides output for falt solar air panel to 14x6 inch register box in small room | 2 |

*Figure 2: Duct work located in the building*

**FOR YOUR SAFETY**
**SUPPLY DUCT SYSTEMS MUST BE INSTALLED ACCORDING TO THIS INSTALLATION GUIDE. IMPROPER INSTALLATION CAN RESULT IN SERIOUS FAILURE OR DAMAGE. WHEN SETTING UP HVAC DUCTWORK, ALWAYS ACCOUNT FOR FACTORS SUCH AS ENVIRONMENTAL CONDITIONS, LOAD REQUIREMENTS, MOUNTING OR HANGING METHODS, SIZING CHOICES, AND APPROPRIATE FASTENING TECHNIQUES.**

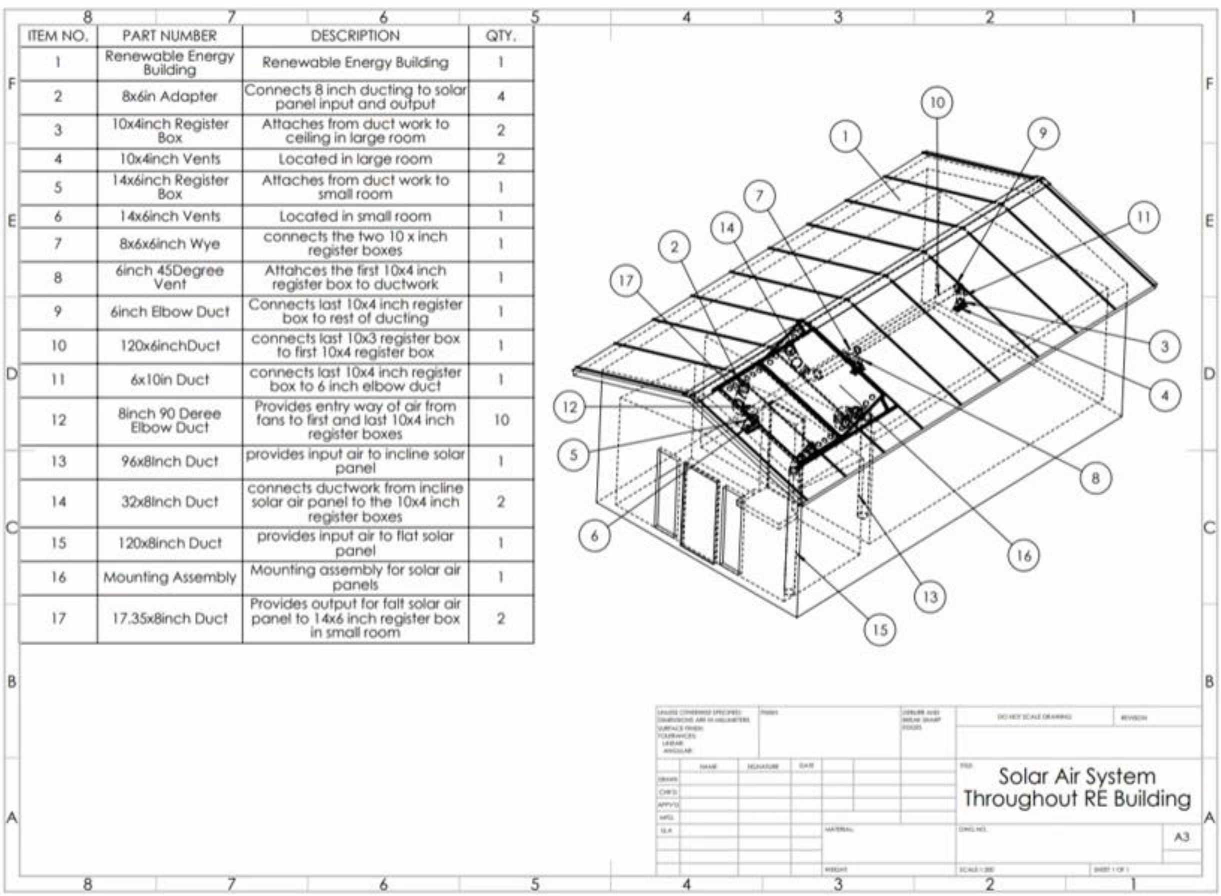



*Figure 3: Duct work located in the building*

*Table 3: Duct Properties*

| Supply Duct Type | Minimum R- value | Space Type |
|---|---|---|
| **Flexible Duct** | **R6** | **Connected to Tilted Solar Air heater in upper half backroom and outlet** |
| **Flexible Duct** | **Flexible R8** | **Connected to both systems and converted to R6 in upperhalf backroom** |

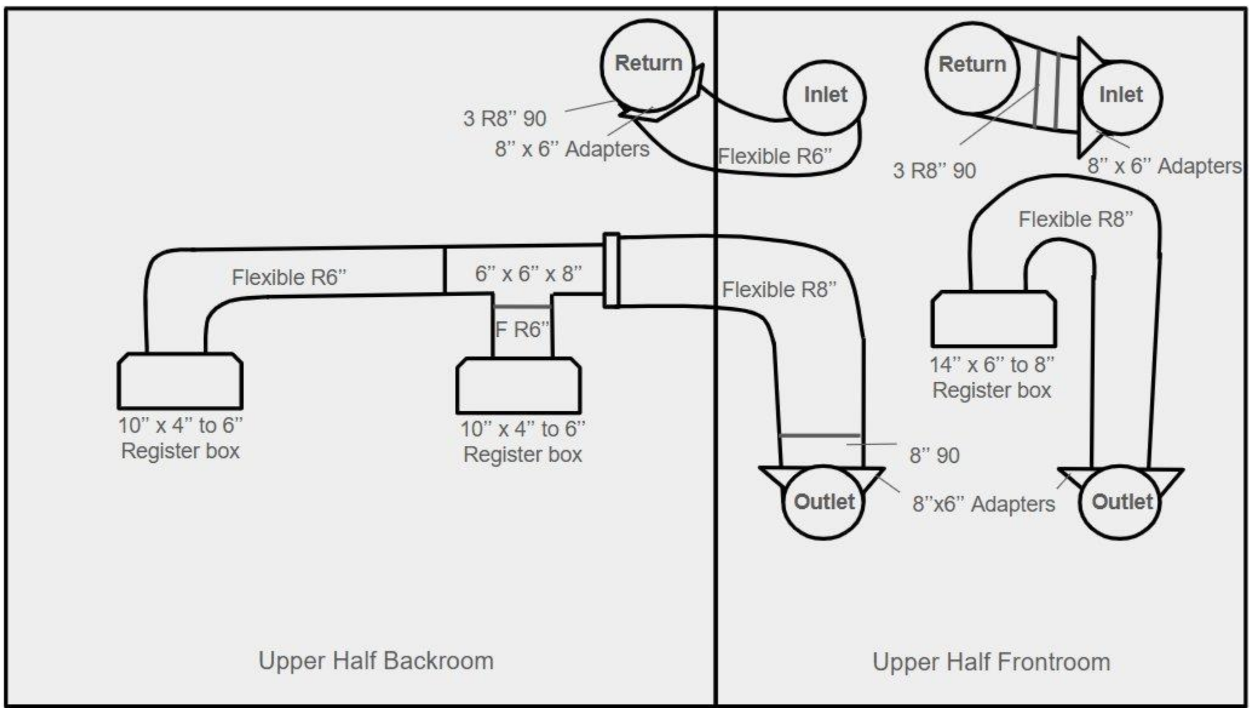



*Figure 4: Duct Flow Diagram*

# Operation

## Hours of Operation

The hours that the SolAir heating system functions vary depending on the date and the weather conditions. The panels will only generate heat if sunlight is incident on the absorber plates, and the Sun’s path in the sky changes throughout the year. A rough month-by-month estimate of the hours of operation of the system is shown in the table below. Note that these estimates reflect cloudless days and the buildings and trees surrounding the RE Lab in the year 2025. The times are <u>not</u> sunrise to sunset. The shadows cast by the surrounding structures prevent the collection of solar energy.

*Table 4: Hours of operation for system to be turned on*

| Month | Heating Start Time (AM) | Heating Finish Time (PM) |
|---|---|---|
| January | 10:30 | 2:30 |
| February | 10:30 | 2:30 |
| March | 8:00 | 5:00 |
| April | 6:30 | 5:00 |
| May | 6:00 | 5:00 |
| June | 6:00 | 7:00 |
| July | 6:00 | 6:30 |
| August | 6:00 | 4:30 |
| September | 7:30 | 4:30 |
| October | 10:00 | 2:00 |
| November | 10:00 | 2:00 |
| December | 10:00 | 2:00 |

## Upon Entering the Building

Ensure that the kill switches for the Ground PV Panel and the batteries are in the "on position" as shown in Figures 5 and 6.


*Figure 5: Ground PV Killswitch in the "ON" Position*


*Figure 6: Battery Killswitch in the "ON" Position*

Press the "ON/OFF" button on the Output Temp Thermometer to turn on the module as shown in Figure 7. The reading on the Output Temp Thermometer may have a lower temperature reading than the temperature of the building. This does not necessarily mean that the system should be left off.

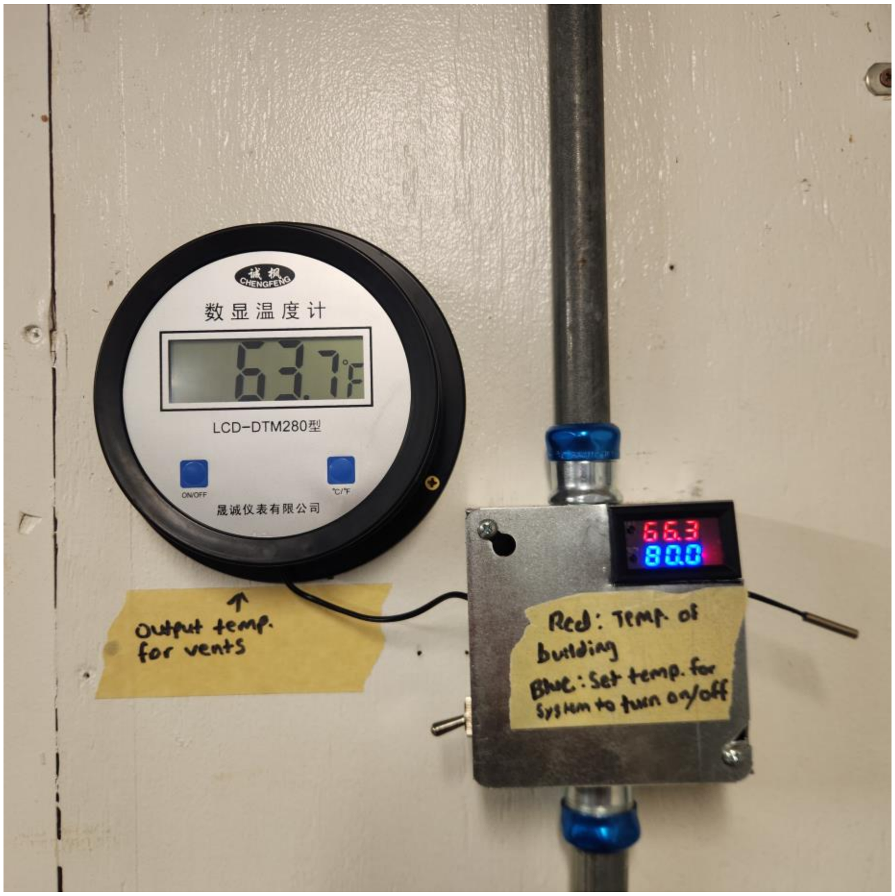



*Figure 7: Thermostats and Master Switch in "OFF" Position*

To test whether the system currently has enough solar energy to heat the building, flip the Master Switch up to the "ON" position to turn on solar air heater system. Let the system run for 1 minute. At this point the air should have circulated enough that you can tell whether the system will be supplying heat or not. If the Output Temp reading is higher than the red Temp of the Building, the system is successfully heating, and it should be left on! If the opposite is true, the system will actually cool the building if left on. Turn both the master switch and the output temp thermometer off to save energy.

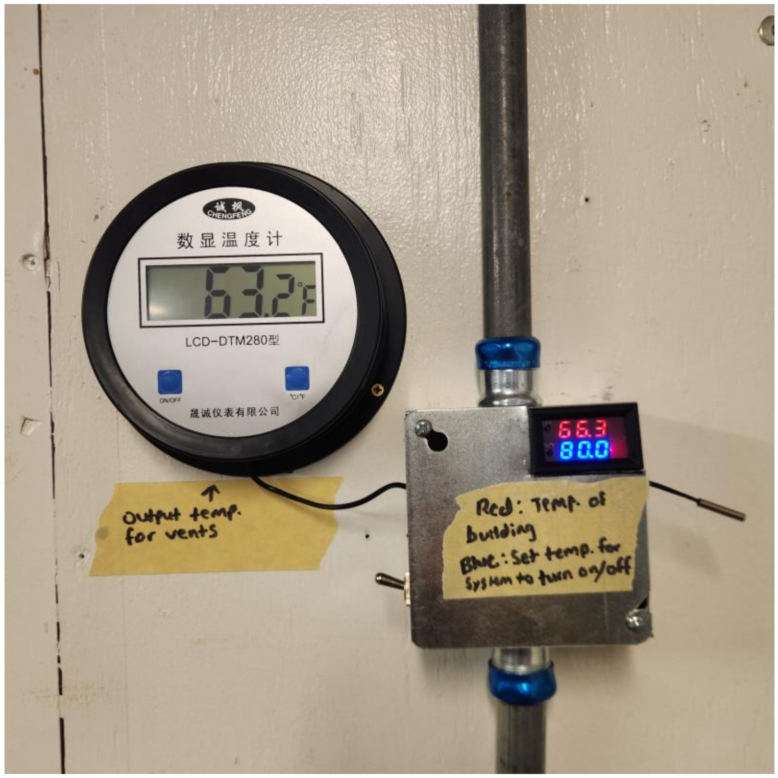



*Figure 8: Thermostats and Master Switch in "ON" Position*

## How to Adjust the Desired Temperature Setpoint

The blue temperature is the temperature setpoint, and the system will turn itself on when the temperature in red is below that setpoint and will turn off when the temperature in red is greater than that setpoint. Below will be simple instructions to change the temperature setpoint which is currently at 80 °F.

To set the desired temperature:

1. Press the **SET** button. The LED display showing the set temperature will begin to flash.
2. Use the **(+)** and **(-)** buttons to adjust the set temperature value.
3. Once the desired temperature is reached, wait for approximately 3 seconds. The module will automatically save the new parameter and exit the setting mode.

## Upon Leaving the Building

Turn off the output temperature thermostat in Figure 7 since it has one triple A battery in the back which the user can change if needed. To change the battery, the user must unscrew the thermostat from the wall to access the back and change the triple A battery. Turn off master switch in Figure 7.

# Maintenance

## Keeping Panels Clean

The panels must be cleaned from time to time to keep the system running at its highest efficiency, especially during snowy conditions. When it is snowing, we recommend cleaning the panels at least once per day. To do this, stand on the east side of the building and use a roof rake to gently pull the snow off the panels. Use caution and be wary of falling ice. Do not climb on the roof to remove snow, ice, or frost! If the panels are frosted, give them time. They will thaw quickly when the sun is out. During all other weather, we recommend cleaning the panels once every three months. Simply sweep with a broom and/or wipe down the panels with a cloth and your choice of cleaning spray to remove leaves, pine needles, dirt, ash, pollen, and dead insects.

## Keeping Inlets Unobstructed

The solar heating system is a closed loop, and it requires minimal obstructions at the indoor intakes to be able to function. Keep cluttering away from the vents shown in Figures X and X to ensure maximum airflow.

## Keeping Ducts Clear

There are mesh covers on each of the vent intakes shown previously to filter out debris, but this mesh is not fine enough to filter small dust particles, which could build up over time and decrease the performance of the system. The simplest way to keep the ducts clean is to keep the RE Lab clean. Sweep or vacuum the areas at least once a month. If buildup happens anyway, either use a shop vac to suction out the ducts or hire a professional cleaner.

# Troubleshooting

## Why is the thermostat or fans not turning on?

Check the kill switch / fuse box shown in figure 5 and the battery power switch in figure 6. Likely one of these switches is turned off. If both switches are turned on and the thermostat is still off, turn off both switches in figures 5 and 6 and open the load box located below the thermostat. Located in the load box is the 5amp fuse and must be checked to see if it was blown. If the fuse is blown, replace it and turn the kill switches back on.

## Why are the vents blowing cold air?

This could be due to several factors obscuring sunlight from the solar air panels. These factors include cloud coverage, trees, buildings, rainfall, and snowfall. The solar air panels collect solar energy, heating the air that comes through the inlet, and allows the fans to distribute the heated air through the duct system. During times when sunlight is not available, the solar air collectors cannot heat the air and thus the fans will be distributing cold air rather than hot air.

### Why is there no airflow?

Check that all power switches are in the "ON" position because if one switch is off the system will not turn on. Reference Figures 5, 6, and 7. Check that inlet ducts are not obstructed or blocked off. Make sure there are no obstructions at the three vent outputs located in the ceiling. If there is still no airflow ducts may be internally obstructed, or the fans may be inoperable and may need replacing.

## Conclusion

The SolAir Heating System uses the power of the sun to heat the RE Lab. If there is sun incident on the panels, there is heat to be had. Use the system with care and keep the surrounding areas clean to ensure maximum efficiency. Keep the output temperature probe and the master switch off when not in use to save energy.