

UPDATE

to Solar Air Collectors

There have been many new developments in the design and construction of site-built air collectors and systems since the publication of "Solar Air Collectors" in 1981. Featured in this update will be the Willett Insert-Type Air Collector and the Porcupine Air-To-Water Heat Exchange Tank. These innovative projects are not only easier to construct, they represent a

considerable increase in operational efficiency over past designs. We will also take a more in-depth look at one of the most cost-effective ways to use the heat your solar air collector delivers - the water heating/space heating, 2-mode system. Finally, we will review the mistakes which are most commonly made by do-it-yourself collector builders.

The Willett Insert Collector

The collector design we present here was developed by Rick Willett, who is a board member of the San Luis Valley Solar Energy Association. Rick installed the prototype on a new machine shop which is part of the family ranch operation near Las Sauces in the rural San Luis Valley. Whereas other successful collectors in the San Luis Valley were built by layering metal track, the framework for Rick's collector is made of a single piece of metal track (or folded sheet metal) which is lined with ductboard insulation. Into this insulated frame, a heat absorber insert (selective surface material, aluminum trailer siding, or galvanized sheet metal) is installed. The absorber insert is sealed on all sides and "floats" in a bed of silicone.

Rick points out the advantages of his collector design over the other wood or metal, owner-built collectors:

- The one-piece perimeter framework is easy to assemble and has a minimum of seams so there is less chance of leakage than with other designs.
- Fewer screws and less silicone sealant are needed for construction.

- The absorber insert forms its own frame and is not connected to the outer perimeter framework. This allows the absorber to expand and contract independently from the outer frame. Since the absorber floats in insulation there is very little heat loss from its edge and collector efficiencies are increased.
- The collector does not require the installation of additional outside insulation which is a time consuming chore.
- The collector body is almost completely self-flashing when installed either vertically or at a slant.

Perhaps the biggest advantage of this collector for the do-it-yourselfer is that it is the easiest to build of any site-built collector we have seen.

Let's look at a photo sequence and construction steps for a collector built to Rick's guidelines. Our example roof mounted collector is built to accommodate 6 panes of 34"x76"x1/8", low iron, non-reflective, "solar glass." The insert absorbers were fabricated from black chrome on aluminum selective surface absorber material. Since this system will be used primarily to heat water it is installed at a slant.

The Willett Insert Collector



Laying Out the Collector and Removing Shingles.

Layout

Layout the collector framework, snap chalk lines and remove the shingles where the base plates will be located. Be sure your dimensions allow for a $\frac{1}{2}$ " space between glass panes, for framing at the top and bottom of the collector, and for exterior siding at the sides. A Skil saw with a carbide nail-cutting (or ruined) blade is useful for removing shingles and for cutting holes in the roof for ductwork. Do not cut roof rafters. One of the two manifolds is shown. It was made from 10" round galvanized ductwork, an adjustable elbow, and three 2"x14" rectangular sheet metal sleeves. The sleeves were specially made at a sheet metal shop.



Framing and Sheathing the Collector and Installing Manifolds.

Framing, Sheathing, and Manifolds

Frame the collector mount over 2"x4" or 2"x6" bottom plates using 2"x6" (or 2"x4") trusses, 24" on center. Assemble the trusses using $\frac{1}{2}$ " plywood gussets attached with 6d nails. Install both end trusses and use a string line to make sure the collector surface is very flat. Shim the trusses or cut them to length if

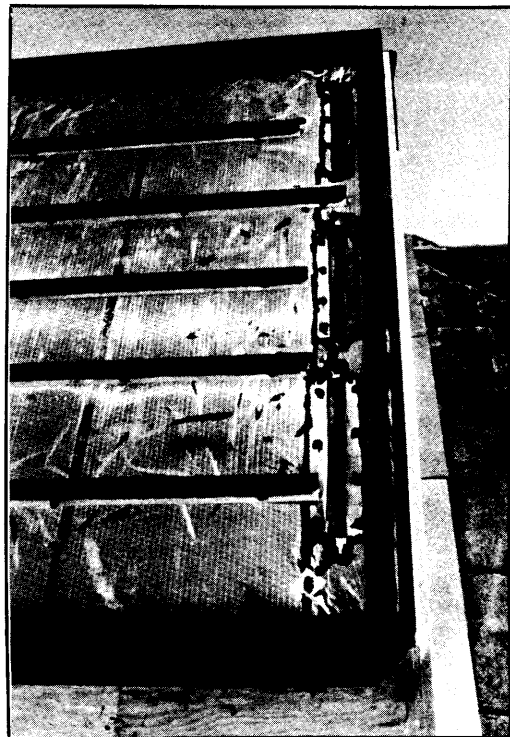
necessary. Sheath the collector mount with $\frac{1}{2}$ " CDX plywood and 8d nails.

Carefully locate the rectangular manifold port openings on the plywood and neatly cut them out. The manifold ports should be long enough to extend 2" to 3" past the plywood after the manifold is secured behind the collector with plumbers strap. Seal all joints in the ductwork with duct tape and/or silicone. Staple $\frac{3}{8}$ " insulation between the trusses behind the collector surface only. In the photo, note the counter-flashing placed under the shingles where the side of the collector meets the roof. The manifolds shown on this collector were attached to metal flex duct but we prefer to use adjustable elbows because they present less resistance to air flow and are just as easy to install.

Perimeter Track and Backing Insulation

Screw the $\frac{3}{8}$ " perimeter track (over a $\frac{1}{4}$ " continuous bead of silicone) to the plywood with $\frac{1}{2}$ " "Zip-In" or Phillips-headed screws. Use a single piece of track for each side and form the top and bottom corners in this piece by snipping the legs. Overlap joints in the top and bottom sections of track. Place two pop rivets in the overlap and silicone seal the joint.

Insulate the back side of the collector with 1" ductboard. Make sure it fits snugly against the perimeter track. Cut and trim the ductboard to create 1" foil faced overlaps that point in the direction of the air flow. Seal them to adjoining pieces with a bead of silicone, and run an additional bead on the outside surface of the joint. Seal the joint between the ductboard and the $\frac{3}{8}$ " track at the perimeter with a generous bead of silicone. Point this bead with a finger.



Sealing Manifold Ports, Installing the Baffles.

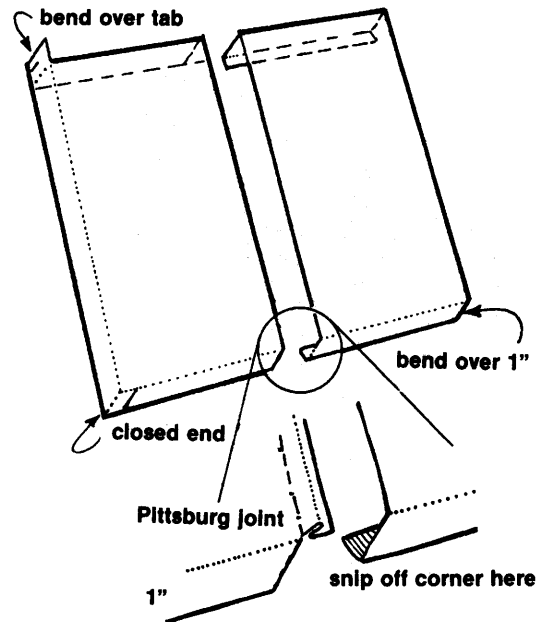
Manifold Ports, Baffles, and Side Insulation

Snip the corners of the rectangular manifold ports and blend out the flanges which are formed at the surface of the ductboard. Run a bead of silicone under the flanges and screw them to the plywood collector backing with $1\frac{5}{8}$ " Phillips sheet rock screws until the ductboard is barely compressed. Use plenty of silicone around the ports to insure an air tight seal.

Snap horizontal lines on the ductboard (12"-18" on center) to place the 1" metal "Z" that will act as air baffles and absorber supports. Start screw holes in the "Z" with a hammer and nail and attach it over the ductboard to the plywood backing with $1\frac{5}{8}$ " screws, 24" on center, until the ductboard is barely compressed. Cover all screw heads with silicone. Smear a film of silicone on the upper surface of the galvanized "Z" to prevent the unlikely possibility of galvanic corrosion between dissimilar metals.

Cut ductboard strips $2\frac{3}{4}$ " wide to fit against the perimeter and snugly inside the $3\frac{5}{8}$ " track. Paint the foil faced surface of these strips with high temperature black paint (for appearance only) and stuff them inside the track. Seal the joints between the ductboard strips and the ductboard at the bottom of the collector and the perimeter track at the top with black silicone. Use foil faced overlap joints between strips sealed with black silicone. Take your time to insure a continuous, air tight seal at both joints.

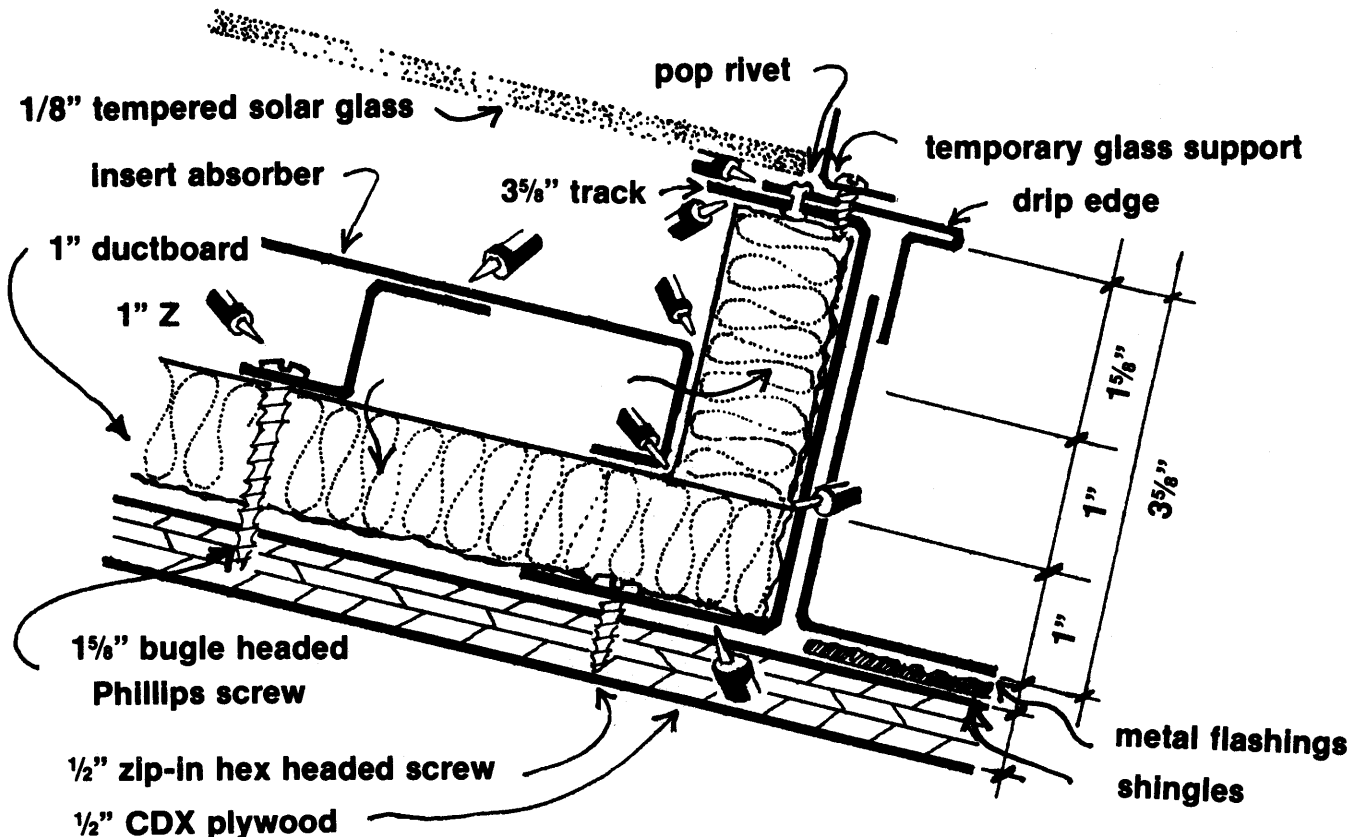
In the photo note that the perimeter track on the side of the collector rests on top of drip edge with a clear



silicone seal on the outside edge. This eliminates the need for additional flashing on the side of the collector.

Insert Absorber Plates

The inserts for this collector were made from "Sunsheet," a textured selective surface, aluminum absorber plate. At a sheet metal shop a Pittsburg joint



The Willett Insert Collector



Installing the Insert Absorber Plates.

is run onto one edge of an absorber plate cut to 79". Two inches of the Pittsburgh joint is trimmed off both ends. The ends are then bent down to create a "J" as in the detail. This is best done on a sheet metal brake but can be done by hand if you are careful. One leg of the "J" rests against the ductboard backing, the other against the ductboard on the perimeter. The furnished vertical height of the insert is 75" so it fits snugly inside the opening for it in the collector. In the photo the Pittsburgh joint on the installed plate on the left has been opened slightly with a slotted screwdriver, filled with a small bead of black silicone, and is ready for the unprocessed edge of the next absorber to slide into it. Make sure these joints are tight and completely sealed with silicone. Secure the insert to each horizontal "Z" with a single 7/16" self-tapping screw through a "chocolate-chip" of black silicone. Seal the perimeter joint between the inserts and ductboard with a generous bead of black silicone and point this bead with a finger to insure an air-tight seal.

Glazing Supports and Glass

Two pieces of 1 1/8" track will snap together, both legs of one piece inside both legs of the other, to form the vertical glass supports. Cut the track to length and leave 1/2" tabs on the upper surface of both ends of the upper section to attach to the perimeter track. Check for fit inside the collector before screwing the two pieces of track together with five 7/16" screws through each side. Avoid twisting the assembly as the screws go in. Clean the surfaces that will be exposed with full strength rubbing alcohol and paint with high temperature flat black paint. Carefully check placement to allow a 1/2" gap between glass panes and pop rivet the tabs to the perimeter framework, top and bottom. The glazing supports will appear flimsy but will stiffen when the glass is set.

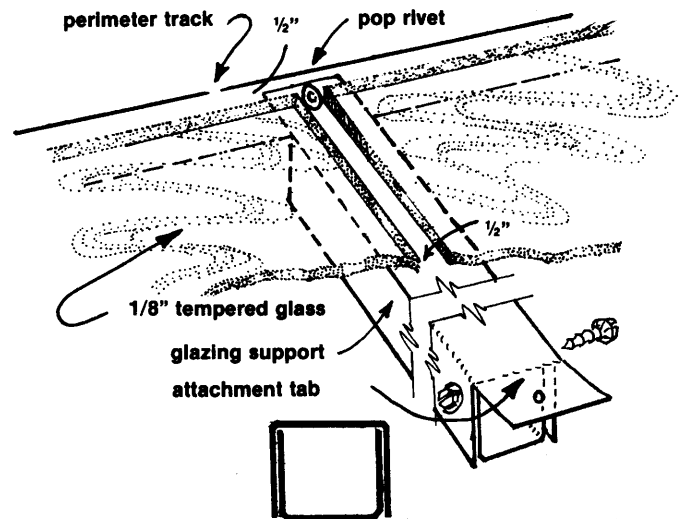
Install bottom supports under the perimeter track at each glass joint. These can be made from pieces of 3" metal angle (shown) or triangular gussets made from

wooden 2"x6".

Pop rivet black painted drip edge to the lower perimeter framework over a generous bead of black silicone. Overlap joints. It may be necessary to rip some types of drip edge to size with snips so that its upper edge is flush with the inside edge of the perimeter track.

Snap a line on the drip edge at the bottom of the collector to locate the bottom edge of the glass. Screw small, temporary glazing support angles at the line near both corners of each pane of glass. Hold them with pliers.

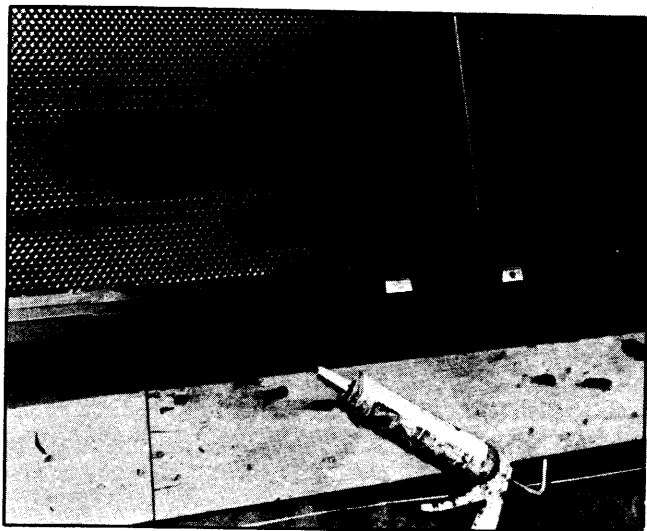
Clean each pane of tempered solar glass and set it in place on the support angles, *textured side in*. Slightly lift up on the edges of the glass, one at a time, and squirt black silicone between the glass and the glazing supports and perimeter track. Make doubly sure the silicone seal is continuous around all edges of the glass. Point the silicone at the edge of the glass with a finger for a neat appearance and good seal.



Glazing Support Detail



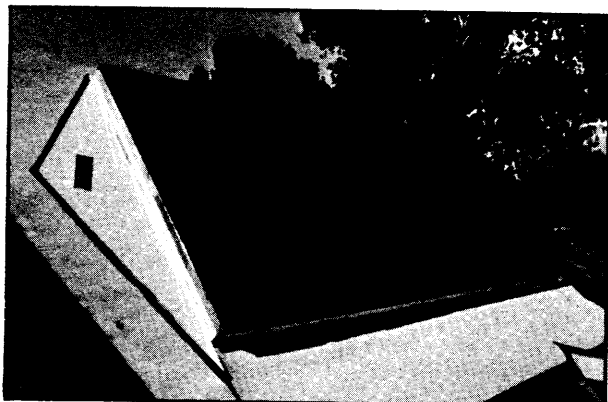
Installing Glazing Supports and Glass.



Bottom Detail.

Bottom Detail

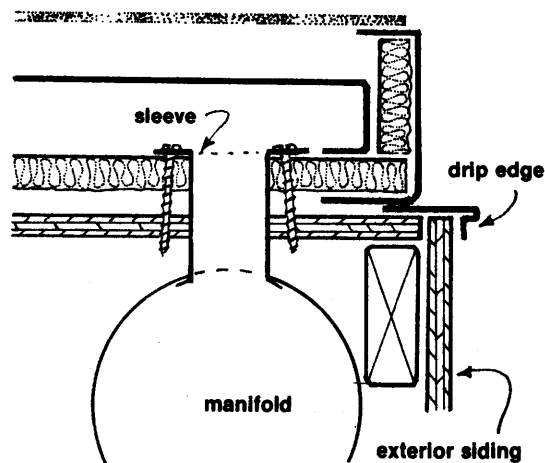
Shown is a close-up of a vertical glazing support, drip edge, temporary glass support angle, installed glass and bottom support. The glass support angles are removed a day or two after the glass is installed and black silicone forced into the small gap under the glass.



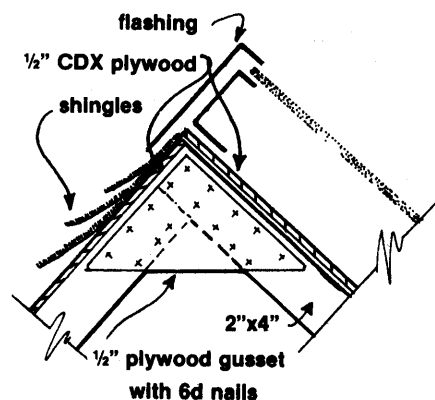
The Finished Collector.

Finished Collector

The shingles on this roof were in poor shape so roll roofing was used to seal the roof until the entire roof could be reshingled. At the top of the collector flashing extends $1\frac{1}{2}$ " over the glass and 8" down over the shingles on the north side. At the bottom, flashing fits up under the drip edge and 3" over the roll roofing. No flashing was used (or needed) between the vertical glass joints or at the sides of the collector. Since this is a roof mount the joints are barely visible from the ground. Coated or galvanized metal flashing can be used for a more attractive installation in ground mounted collectors. This collector is a good size to be used for a 2-mode system — heating water in the summer and providing space heat in the winter.



Side of Collector and Manifold Detail



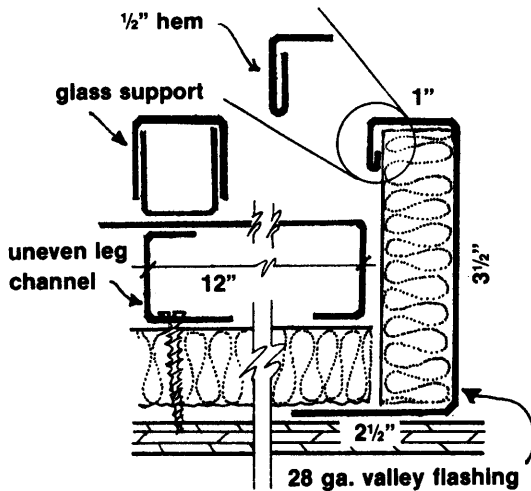
Top of Collector

Additional Tips

Perimeter Framework

The design we present uses exterior-type, $3\frac{5}{8}$ " metal track with $1\frac{1}{4}$ " legs for the perimeter framework because it is a standard item that is readily available. Rick Willett prefers to have the framework made on a sheet metal brake from 28 ga. galvanized sheet metal as shown in the detail. The dimensions for his perimeter track are chosen to allow 8" wide, galvanized, valley tin (roof flashing) to be used in making these pieces. Although special made track from the sheet metal shop can be three times as expensive as standard track, it is easier to work with because it is more rigid. Painting the ductboard at the side of the collector is unnecessary and it is possible to attach the glazing supports with additional side tabs which provides more strength at these points. The added lip at the top of the perimeter track makes it easier to seal the top edge of the ductboard insulation and allows small metal angles to be temporarily inserted under them, holding down the edge of the insert during construction.

Willett Cross Section



Absorber Supports

The metal "Z" absorber supports/baffles can also be made at the local sheet metal shop. Standard "Z" with an installed height of 1" is recommended in insert collectors with a 16-24' air flow length through the collector. Special "Z" with a height of $\frac{3}{4}$ " is useful in collectors with a 12-16' air flow path. Unequal leg track (1"x1"x2", 28 ga.) also works well for absorber supports but must be special made.

Selective Surface Absorbers

We like selective surface absorbers and most site-built collectors currently being installed use black chrome on aluminum. This material is relatively new on the market, and considerably cheaper (\$2.00/sq. ft.) than black chrome on copper (\$3.50/sq. ft.). The only thickness presently available from Berry Products is 8 mil and it is adequate, but 12 or 15 mil material would be easier to work with in insert collectors. Self-adhesive, selective surface foil is a good choice for "rolling on" over 30 ga. galvanized steel plates. Although there are several "selective paints" on the market, we haven't been impressed with their selective performance.

Solar Glass

We recommend using non-reflective, low-iron, solar glass for glazing. It not only allows more light to reach the absorber but, most importantly, you can't see through it into the collector and the installation is much more attractive. The price of solar glass has come down dramatically in the last few years and most solar suppliers offer it at a price only slightly higher than regular tempered glass. Solar glass $\frac{1}{8}$ " thick is more economical and easier to handle than the more common $\frac{3}{16}$ " thickness. The thinner glass is perfectly adequate unless large hail or vandalism are common at your site.

Cleaning Galvanized Steel

All galvanized track used for collector construction must be very well cleaned before sealing with silicone caulk or painting. At the very least, clean all surfaces with full strength rubbing alcohol. It is a good idea to further treat galvanized metal with "Galva-Prep" (or other priming solution) available at most hardware stores. Silicone caulk adheres well to treated sheet metal but even better to treated and painted surfaces.

Sources Of Supply

Track - All drywall supply stores and most sheetrock contractors offer metal track and "Z". In the $\frac{3}{8}$ " track, look for exterior (.036" thickness) rather than interior (.020") track and use track with legs $1\frac{1}{4}$ " long. Ask for "Z"-channel (.020) with $\frac{3}{4}$ "x1"x $1\frac{1}{4}$ " dimensions. Metal Stud Framing Corp., Box 450, Commerce City, CO 80037, has offices in Texas and Arizona and can drop ship larger orders. Their order numbers are: $\frac{3}{8}$ " track, $\frac{3}{8}$ ET, Z-channel, 1-ZC.

Selective Aluminum - Berry Solar Products, P.O. Box 327, Edison, NJ 08817, manufactures selective aluminum absorbers. Their catalogue lists plates with 5 to 20 mil thicknesses but only 8 mil is presently available. Twelve or 15 mil would be best for inserts. Berry sometimes doesn't sell small orders to individuals, but they can send you to a dealer.

Ductboard - Your local sheetmetal shop or plumbing and heating contractor is the best bet here.

Silicone - Write Cadillac Plastics, P.O. Box 33011, Drawer 8, Detroit, MI 48203, for their nearest branch office. They offer the best case prices around.

Static Pressure In Collectors

A certain amount of static pressure (resistance to air flow) is desirable in all air collectors because it promotes heat transfer from the absorber plate to the moving stream of air. Many collectors are built, however, that have an excessively high static pressure. This is usually the result of either a convoluted air flow path through the collector or restrictions as air enters and leaves the collector.

Straight air flow paths or those with only a single turn are the recommended choice for all collectors,

especially the insert-type. If the air must make a turn in order to travel 20 feet behind the absorber, install turning vanes in the air flow cavity to help direct air around the corner. Several short (8") vanes installed fairly close together (8-12" on center) work better than a single turning vane.

Proper manifolding of larger collectors will insure that the air flow isn't restricted as it enters and leaves the collector. Manifolds are easy to build from either round or rectangular ductwork with either floor

register boots or rectangular sleeves attached. Be sure that the boots or sleeves that feed and exhaust the collector are long and narrow so that they have nearly the same cross-sectional area as the air flow cavity. Don't use round ductwork for manifold ports (or for attaching directly to small collectors) because static pressure problems can arise.

The static pressure in collectors with a 20 foot air

flow path through a 1" deep air flow cavity will be:

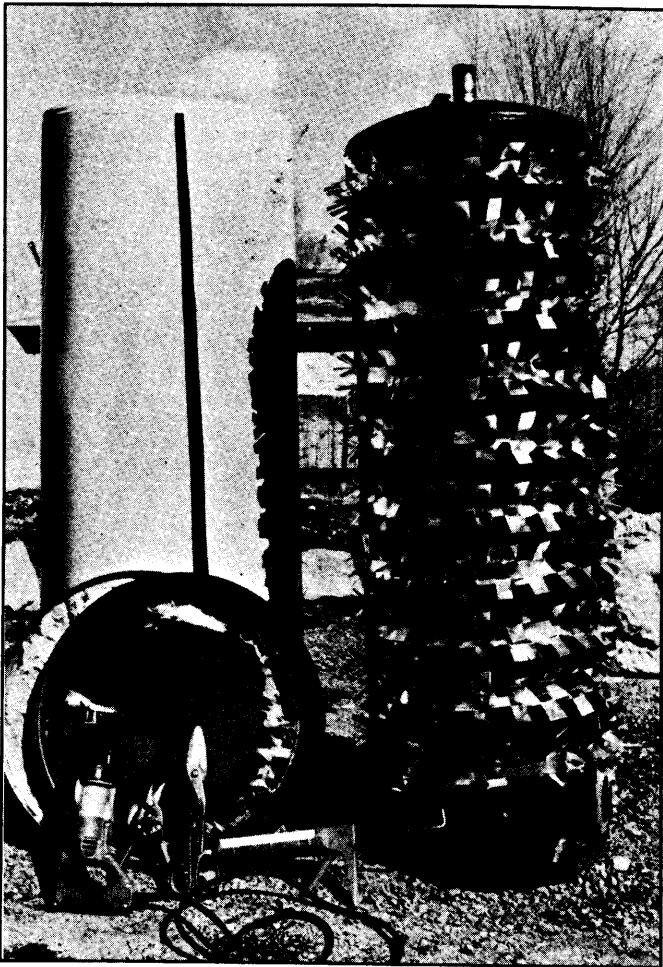
Straight Pass - large rectangular ports in manifold
= .20 - .25" WG

Convolved Pass - Undersized or round ports = .30
- .40" WG

There is a big difference between a static pressure of .20" and .40", so design the baffling and manifolding in your collector carefully.

Porcupine Heat Exchangers

This section is excerpted from "Solar Flashes," September, October and November issues, 1982, and used with permission of Rodale Press.



A "porcupine" air-to-water heat exchanger tank for an active solar air heater is easily made by stripping the jacket from an 80 gallon storage tank. Bands are attached to the outside of the tank before replacing the jacket. Solar heated air encircles the tank and moves in a closed loop between the collector and the tank.

Solar contractors and do-it-yourselfers in the San Luis Valley have been working with different types of air-to-water heat exchangers for several years. The result of a lot of trial and error and a good tip from W. Scott Morris of Santa Fe, New Mexico, is the Porcupine Tank-Type exchanger presented here. This exchanger is so easy to build that it represents a good do-it-yourself project even for those of you who are unsure of your plumbing skills. It is also very economical to build and should cost 1/3 as much, or less, than the more widely used induct type heat exchanger while providing the same, or better, exchange efficiencies.

The Porcupine Tank shown is built from an 82 gallon hot water storage tank which is a lot like a typical water heater. It consists of an insulated tank enclosed in a sheetmetal jacket. To build the exchanger, the jacket is stripped from the tank and the insulation is removed from between the jacket and the tank. The jacket is replaced around the tank and solar heated air is blown into the top of the space between jacket and tank. The air encircles the tank and returns to the collector in a closed loop. Efficiency can be increased if fins are attached to the outside of the tank to increase its surface area and promote better heat transfer. In the most effective tank design, these fins are formed by attaching bands to the tank and bending out tabs to create a "porcupine" tank.

Materials:

1. 82 gal. glass lined water storage tank (without heating elements)
2. 18 sheetmetal bands; 4" wide and equal in length to the tank circumference plus 2".
3. 12, 1 1/4" #10 bolts with two washers each.
4. Two tubes of silicone.
5. 36, #8x1/2" sheetmetal screws.
6. Temperature and pressure relief valve (20,000 BTU's/hr.)

Prepare The Tank

Locate and purchase a new 82 gallon glass lined, hot water storage tank (\$270-300) without heating elements. Smaller systems with less than 80 square

Porcupine Heat Exchangers

feet of collector can utilize a smaller tank. A tall tank will have more surface area for heat transfer than a short, squat tank, so buy the tallest tank available. We suggest buying a new tank rather than using a recycled hot water heater because you never know how much life an old water heater has left in it. Do not use a galvanized tank. The important thing is that the tank have $1\frac{1}{2}$ " or more of insulation since this is the space we need.

Plan your plumbing fittings to the tank and loosen all of the fittings on the tank. Remove the screws (or drill out the pop rivets) holding the round jacket end caps in place on both ends of the tank. Set the tank on its side and pull off the ends. If the tank is insulated with fiberglass batts, pull these out and remove the jacket in one piece. If the tank is insulated with foam, as most new ones are, slit the jacket lengthways using a jig saw with a short (1") metal cutting blade. Dig out the insulation as you peel the jacket off. If foam insulation is stuck to the jacket, tank, or end caps, scrape it off with a chisel and use a wire brush to clean the surface.

Before attaching the bands to the tank, lift up the tank and set it vertically onto the bottom jacket end cap with insulation under the concave bottom of the tank. Center the tank over the end cap and run a large bead of silicone around the bottom of the tank to seal off the perforations that will be present in most end caps. Let the silicone cure for a day or two before moving the tank or putting the jacket back in place.

Install The Bands

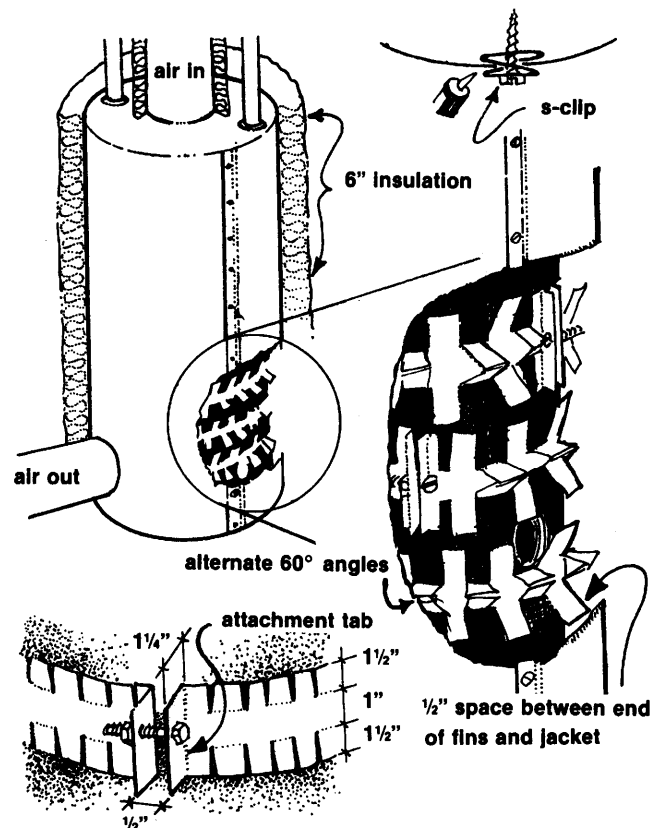
Since our example tank has two inches of insulation between the tank and the jacket, the bands required for it will be four inches wide. In this way, the tabs will extend $\frac{1}{2}$ " from the tank and a $\frac{1}{2}$ " air space will be created next to the jacket. A 1" wide "bridge" section will attach the band to the tank. If your tank has more insulation, use wider bands, but be sure to leave a $\frac{1}{2}$ " space next to the jacket or the tank will have very high static pressure. The bands should be as long as the circumference of the tank plus 2" for the attachment tabs. Cut the bands yourself from valley tin (roof flashing) or have them cut from 30 ga. sheetmetal at a sheetmetal shop.

Install the first band before cutting up the rest of the bands so you will get a feel for things. Wrap the first band around the tank and bend up both ends $\frac{1}{4}$ " at a 90 degree angle. When held tightly around the tank, these attachment tabs should be $\frac{1}{2}$ " apart. This is a critical measurement. Remove the band and drill a $\frac{1}{4}$ " hole in both attachment tabs while holding the band with vise-grips. The edge of the hole should be $\frac{1}{8}$ " from the bend in the tab. Cut $1\frac{1}{2}$ " deep slits in both sides of the band every inch. Try to make the slits opposite from each other. Don't bend the tabs up yet. Run a $\frac{1}{4}$ " round bead of silicone down the center "bridge" portion of the band that will be attached to the tank.

With help from an assistant, carefully position the first band on the lower portion of the tank. Pull it tight and have your helper hold it in position while you bolt

the two support tabs together. Use $\frac{1}{4}$ ", #10 bolts with a washer on both sides. Bolt the band on very tightly and then immediately bend up the tabs at alternate 60 degree angles as in the illustration. If you have used the proper amount of silicone, a small amount should squish out around most of the edges. This silicone attachment should be as thin as possible, while eliminating any air gaps between the band and the tank. Silicone is not a great conductor of heat, but it is the best material (at a reasonable price) for attaching the fins. Other adhesives either don't make a good bond, or are astronomically expensive.

Plan ahead when placing bands near fittings and cut off or bend over tabs where necessary. Place the bands as closely together as possible (the more the better) while still allowing yourself room to bend up the tabs.



Install The Jacket And Boots

Wrestle the jacket onto the lower end cap and secure the jacket to the cap in one or two places by drilling $\frac{3}{32}$ " holes and drive in #8x $\frac{1}{2}$ " sheet metal screws. If you have to split the jacket, attach the two sides with a long S-clip (from the sheet metal shop) and screws, or with a sheet metal "band-aid." Finish attaching the jacket to the bottom cap with screws about every eight inches.

Cut an 8" round hole near one edge of the top end cap and another near the bottom of the tank using aviation snips. Install short sections of 8" ductwork to these holes with four tabs outside the jacket and screwed to it, the other tabs bent over inside. The tabs

will be different lengths on the lower boot so they will fit snugly around the jacket. Silicone seal joints completely air tight.

Place the top end cap on the jacket so that the 8" "hot" extension for ductwork is more or less opposite the lower exhaust extension. Secure the top end cap to the jacket with screws 8" on center. Don't silicone seal seams at this point.

Pressure Test - Seal And Insulate

Set the tank on a square of 2" rigid insulation where it will be located in your solar installation. Plumb the tank to the water supply and fill the tank. Manually open the pressure relief valve to bleed off air while filling.

Once the tank is filled and pressurized, check for leaks, then silicone seal the joint that the top and bottom jacket caps make with the jacket and vertical seam in the jacket if it was split. Cut sheet metal covers for all holes through the jacket and silicone and screw these into place. Seal around all plumbing penetrations. The jacket must be completely air tight.

The storage tank must be very well insulated. Wrap 6" insulation around, and on top of, the tank and secure with wires. Make sure the pressure relief valve is long enough so that an over-flow of water won't soak the insulation.

One Tank Systems

One-tank systems can be built using a porcupine tank type exchanger by cutting the jacket two thirds of

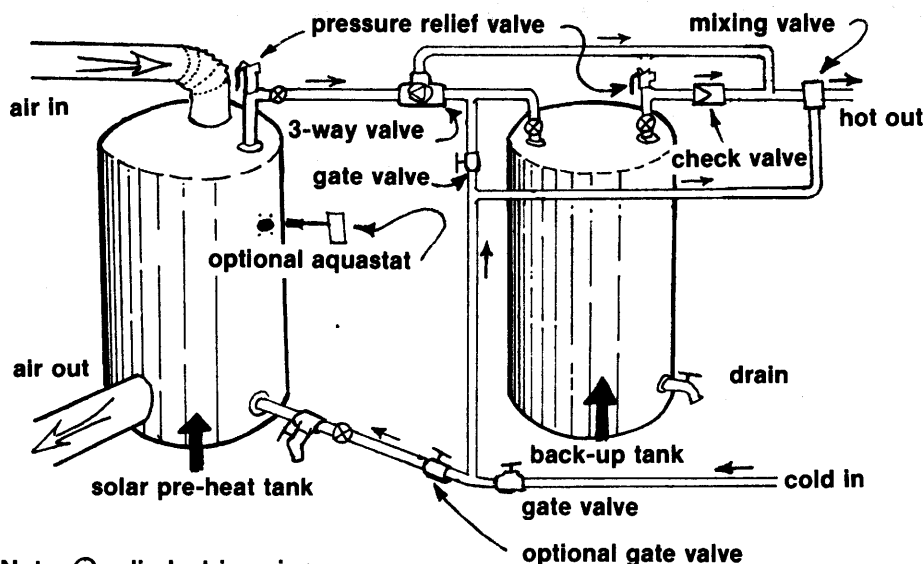
the way up the side of a 120 gallon tank. (Look out for electrical wires inside the jacket that run between the heating elements.) Remove the lower jacket section and attach the bands to the tank, leaving a 4" space top and bottom to act as a manifold for distributing air around the tank. The upper third of the jacket is left in place with insulation underneath. The hot air duct is located opposite the cold return to the collector and a band of sheet metal seals the horizontal joint in the jacket.

Most electric water heaters and hot water storage tanks have top and bottom heating elements, or fittings, to allow for them. If the exchange tank is made from this type of tank, the bottom electrode can be disconnected. The top electrode is left in place (or installed) to heat the water in the top of the tank if there isn't enough solar input. One-tank systems work well because there is much more heat stratification in a tank that is only being heated at the top than there is in a conventional tank type exchanger or hot water heater.

Plumbing

When designing your plumbing system, keep all pipe runs to a minimum. This won't be a problem if you locate the solar pre-heat tank near your hot water heater.

Slope your pipes at least 1/4" for each foot of run and put a stop and waste valve at the lowest point in the system to be able to drain the pipes. Don't skimp on valves. Consider using 3-way valves in suitable



Note: (X) = di-electric union

Shown is an elaborate plumbing set-up for a tank type exchanger. A 3-way valve allows the back-up heater to be by-passed in the summer. An aquastat controls dampers that divert air away from the pre-heat tank when it is hot enough. A tempering valve adds cold water to the outgoing hot water when it is above 130° and should never be omitted unless the collector is very small in relation to the tank. The optional gate

valve and a short line allow bypass of the pre-heat tank for replacement.

In a simpler set-up, warmed water goes directly from the pre-heat tank to the existing water heater with no valves for bypassing. In either case, both tanks require temperature/pressure relief valves and di-electric unions.

Porcupine Heat Exchangers

locations. They are easier to install than two gate valves, cost about the same, and help simplify the plumbing.

Hook-ups between galvanized pipe or fittings (usually at the pre-heat tank) and copper pipe or brass fittings must be made with dielectric unions (or plastic adapters) to prevent galvanic corrosion from taking place.

Be sure to install mixing (tempering) valves on the hot line to the house unless the collector is very small in relation to the solar pre-heat tank. If no hot water is used during a sunny day, water in the solar tank can reach scalding temperatures.

Additional Tips

Sizing

Most residences use close to 20 gallons of hot water per person per day. So, an 80 gallon solar tank is about right for a family of four. If you are very energy conscious or have a small family, a 50-gallon porcupine tank will be sufficient. You will need 1¼ to 1¾ sq. ft. of collector to heat each gallon in the storage tank depending upon your site and the desired percentage of hot water needs you want to be met by solar.

Collectors For Water Heating

The collector must be mounted at a slant (latitude)

rather than vertically. Delivery temperatures must be higher for heating water than for space heating so use selective surface absorbers and move less air through the collector (2 CFM/sq. ft. of collector at sea level, 3 CFM at 5000'). Use plenty of insulation (3½") on return as well as delivery ductwork.

Differential Thermostat

An 8°-18° differential thermostat is a good choice for a water heating system. Mount the cool (storage) sensor in the return air stream at the bottom of the tank rather than on, or in, the tank itself.

Static Pressure

An 80 gallon Porcupine Tank with fins ½" from the jacket will present the following static pressures: .20 inches WG for up to 250 CFM; .34 inches for 300 CFM, and .60 inches for 400 CFM. Optimal air flow for this tank will be between 250 and 300 CFM.

Sources Of Supply

Storage Tanks - Look in the Yellow Pages under "Plumbing Fixtures and Supplies." Shop around - prices vary greatly. If your system is small and you can use a 50-gallon storage tank, your best bet may be to buy an electric hot water heater on sale and remove the heating elements. W.W. Grainger is a good source for suitable water heaters.

Water Heating Two Modes

NOTE: The information in this section relates to pages 22 and 23, Two Mode Systems, in "Solar Air Collectors."

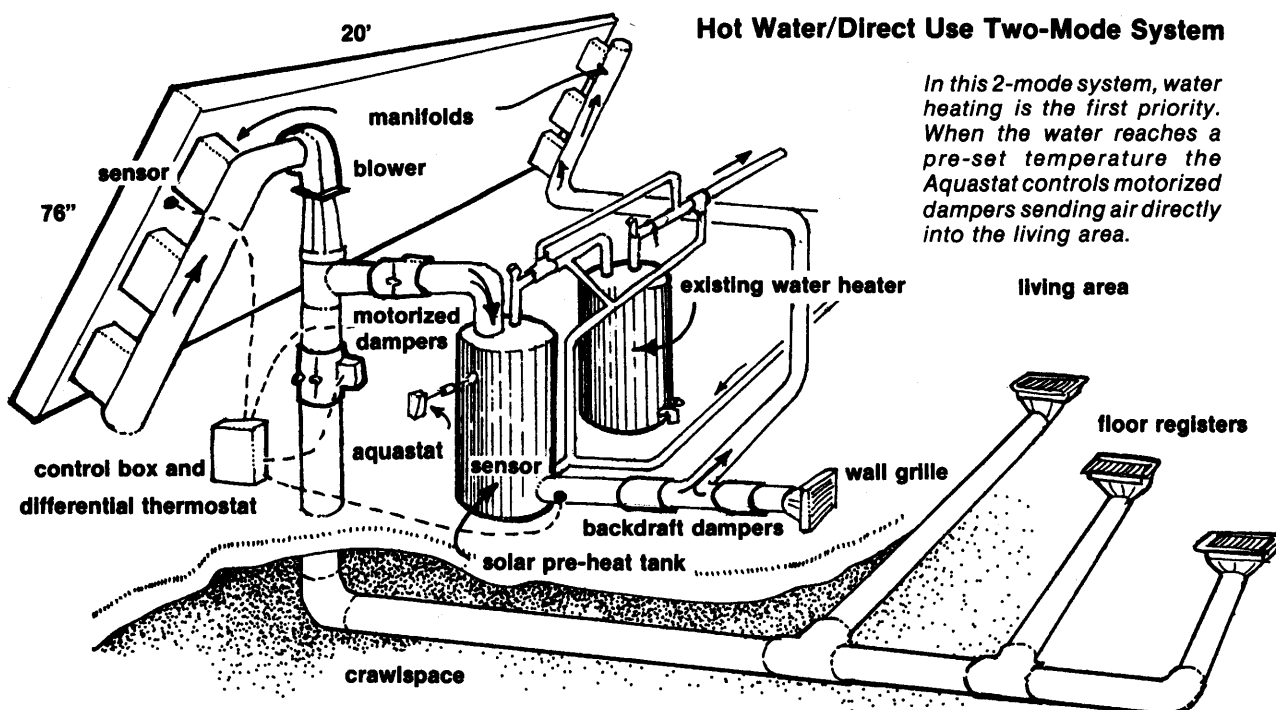
We are very enthusiastic about systems that have two points of use, such as the direct use/crawl space 2-mode system covered in "Solar Air Collectors." In most cases a 2-mode system is better able to use the heat delivered from a collector than a system with only one point of use. They are also usually much more cost-effective in retrofit situations than elaborate 3 or 4-mode systems that incorporate rock storage. Of the many possibilities for 2-mode systems, the set-up that has gained the most popularity in the last few years is the hot water/direct use 2-mode system. Water heating is almost always the first priority, space heating, second priority. A system of this type is particularly effective if the collector is slightly oversized for heating only hot water or larger than 1¼-1½ sq. ft. of collector per gallon of water in the pre-heat storage tank.

In operation this system is quite simple. The porcupine storage tank has an adjustable thermostat mounted on it called an Aquastat. This thermostat senses the temperature of the water in the tank and

controls dampers which send solar air either to the tank (first priority) or directly to the house. In the summertime the Aquastat is set at 180° and the "oversized" collector delivers all of its solar heated air to the pre-heat tank in a closed loop. On many summer days a large collector can heat a tank of water nearly to this temperature and provide all of a home's hot water.

In the wintertime the system has two modes of operation: Heat is delivered either to the storage tank or directly to the living area. The winter setting for the Aquastat on the pre-heat tank will be much lower (90° - 100°) and when the tank has been heated to this temperature, dampers divert heat from the collector to the living area. The collector operates efficiently in both modes and the "excess" heat from an "oversized" collector is very useful for space heating. As less heat is needed for space heating (in the spring and fall) the setting on the Aquastat is raised, allowing more solar heat to be used for water heating. In most installations the Aquastat only needs manual adjustment three or four times a year so it isn't a burdensome chore. Note that two backdraft dampers are required in this system; one from the living area and one from the storage tank.

A 2-mode system of this type is easily adaptable and



can be built in stages. Initially, manual dampers can be used to send solar air either to the tank or to an insulated crawlspace. Later distribution ductwork to the house and electrical controls and dampers can be added.

The big advantage this system has over other 2-mode systems lies in the fact that the collector can be used year-round and the installation will have a rapid payback. The collector also operates more efficiently in the winter space heating mode when there is less sunshine and more need for heat. A final note: if the collector is larger than 2 sq. ft. of collector per gallon of water in the storage tank, you will need to install manual dampers to feed and exhaust the system to the outside air. This will prevent the water in the pre-heat tank from reaching boiling temperatures.

Sources Of Supply

Dampers and Controls - Hot Stuff Controls, Inc., P.O. Box 306, La Jara, CO 81140, offers a complete line of manual and motorized dampers as well as backdraft dampers. They also custom build controls for 2, 3, and 4-mode systems and offer wiring schematics.

Differential Thermostats - Buy D.T.'s that have adjustable high and low set points. Write Heliotrope General, 3733 Kenora Dr., Spring Valley, CA 92077, and NOW Devices, Unit E, 7975 E. Harvard Ave., Denver, CO 80231.

Mistakes To Avoid

Not Seeking Advice

The single biggest mistake most solar do-it-yourselfers make is not seeking expert advice before starting construction. Don't try a new idea of any kind without talking to at least two people who know the basics. If you are building a simple system (collector, greenhouse, or Trombe wall), an "expert" can be anybody who has built two or more similar systems and you can usually find free advice. If you are planning a complex system, consult a professional and plan on spending money for the help. Don't build a \$7,000 mistake.

Evaluation Of System Performance

Efficient collectors run cool. The temperature differential between air entering and leaving a collector should be 40-50° F for most uses. Measure the temperature differential in your collector. If it is above these figures there isn't enough air moving through the collector and you need a larger blower or larger ductwork. Feel the glazing on your operating collector at noon on a sunny day. If it is hot (above 120°) you are losing too much heat from the collector and it is operating inefficiently.

Mistakes To Avoid

Avoiding The Sheetmetal Shop

It is very difficult to build a collector without at least one trip to the sheetmetal shop to have items specially made. The sheetmetal shop is a tremendous resource - don't avoid going. Find a friendly owner who likes working with do-it-yourselfers and take his advice. He may not know about collectors, but he certainly knows about moving air.

Heat Storage

We estimate that 80% of all do-it-yourself rock bins for heat storage could operate better and close to half are complete disasters. Rock storage can be effective, but certain design considerations must be met. Adding storage to a system with a collector which is too small is a common mistake which represents unrealistic expectations of a collector's output. Unless you have "excess" heat to store, storage is wasted money. In almost all cases a collector needs to be larger than 200 square feet to justify the added expense of a rock bin.

Once a bin is built, problems can arise from: horizontal or one direction air flow through the rocks, improperly sized rock, too much or too little rock, improper length of air flow, improper tie-in to back-up system, and over-complicated air flow schematic. With all of these considerations, take our advice and *never* attempt rock storage without consulting a professional.

Storing Greenhouse Heat

Do not use a blower to store greenhouse heat in a rock bin. Greenhouse air is very humid (it has a low dew point) and it will be next to impossible to prevent condensation in the rocks. Mold and mildew will result and the bin can become a stinking, useless, biology experiment. Likewise, don't blow a great deal of humid greenhouse air into or under the house or your house will start to rot after 10 or 15 years, even in dry climates.

Use a lot of mass in the greenhouse (such as water barrels) and open the door to it to let some heat enter the living space. Using an air-to-air heat exchanger is the only safe way to move a great deal of air from a greenhouse to storage or living area.

UPDATE

This UPDATE was prepared by: Rick Willett, Andy Zaugg, Bob Dunsmore, Steve Kornher, Mike Wagner, Terry McClaghry, and members of the San Luis Valley Solar Energy Association.

Illustrations by: Austin Canon

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Lack Of Dampers

Don't leave out the dampers. Dampers are, of course, needed in complex systems to direct air to the point of use but even simple systems require a backdraft damper and often a motorized damper at some point in the system. At night, systems without dampers can lose one third or more of the heat they gain during the day. In systems that heat an insulated crawlspace and/or domestic hot water it will be especially difficult to observe the heat losses that occur from a lack of dampers.

Blower Mounting

You can hook-up the motor on a blower so that it rotates in the wrong direction. The system will seem to be working, but working very poorly. Several "experts" have made this mistake and been confused for days before switching the wires to the motor. This isn't a problem with pre-assembled blowers.

Oiling The Blower

The motor on all squirrel cage blowers requires oiling once or twice a year. Be sure to locate the blower so this is easy to accomplish.

A New Book

There is a new book out by Rodale Press that really covers the ground on solar air systems, "The Complete Handbook of Solar Air Heating Systems" by Steve Kornher, with Andy Zaugg. It takes an in-depth look at the many ways to use solar heat, collector design theory and the economics of solar heating. Step-by-step construction details are given for two thermo-siphoning air systems, the window box collector and TAP, as well as details and options for building active collectors. The chapters on ductwork design and blower selection, water heating, and construction of a thermal storage rock bin are especially useful. The emphasis is on do-it-yourself retrofit. This book will be available in November 1983 from the SLV-SEA for \$17.95 plus \$2.00 postage.

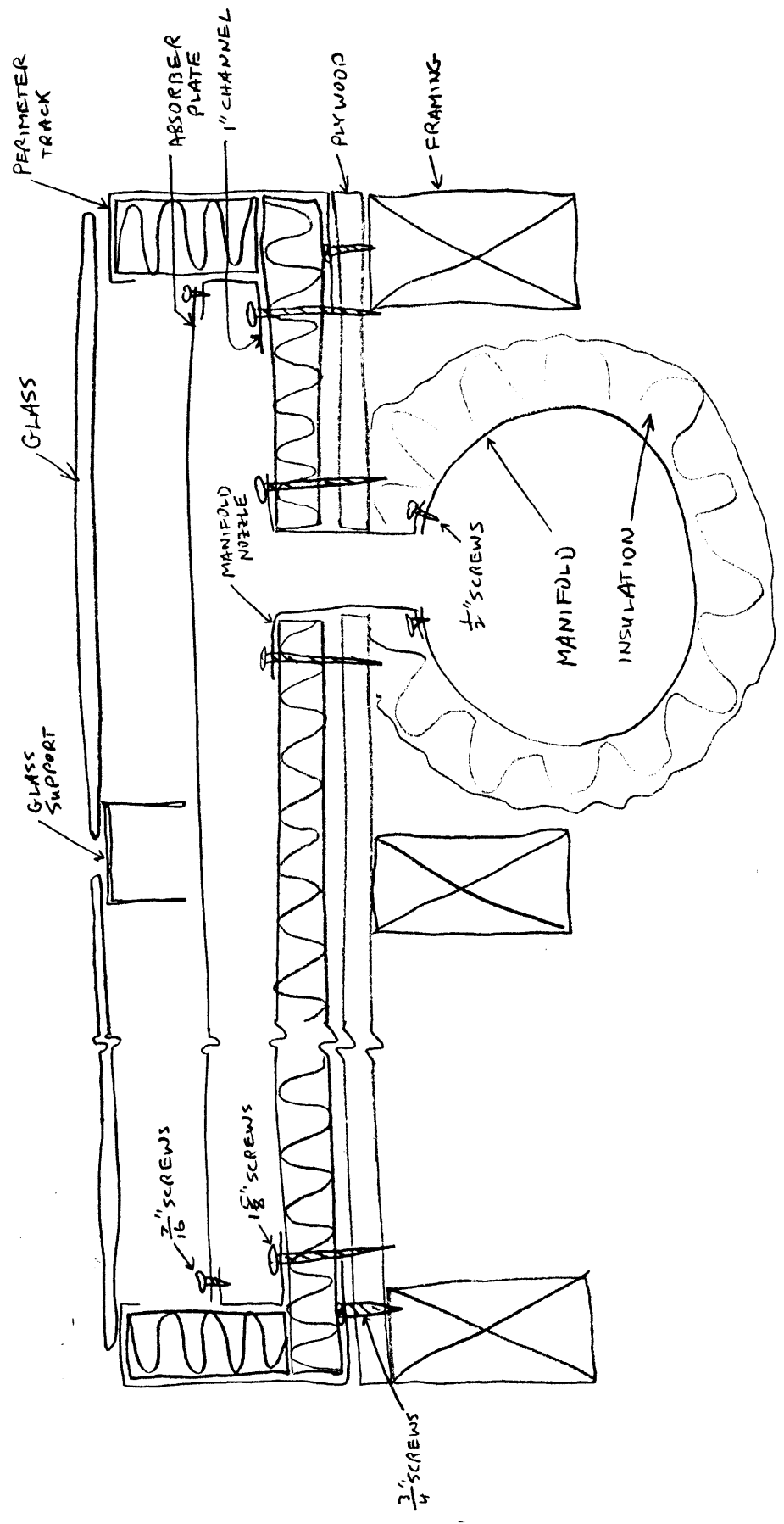


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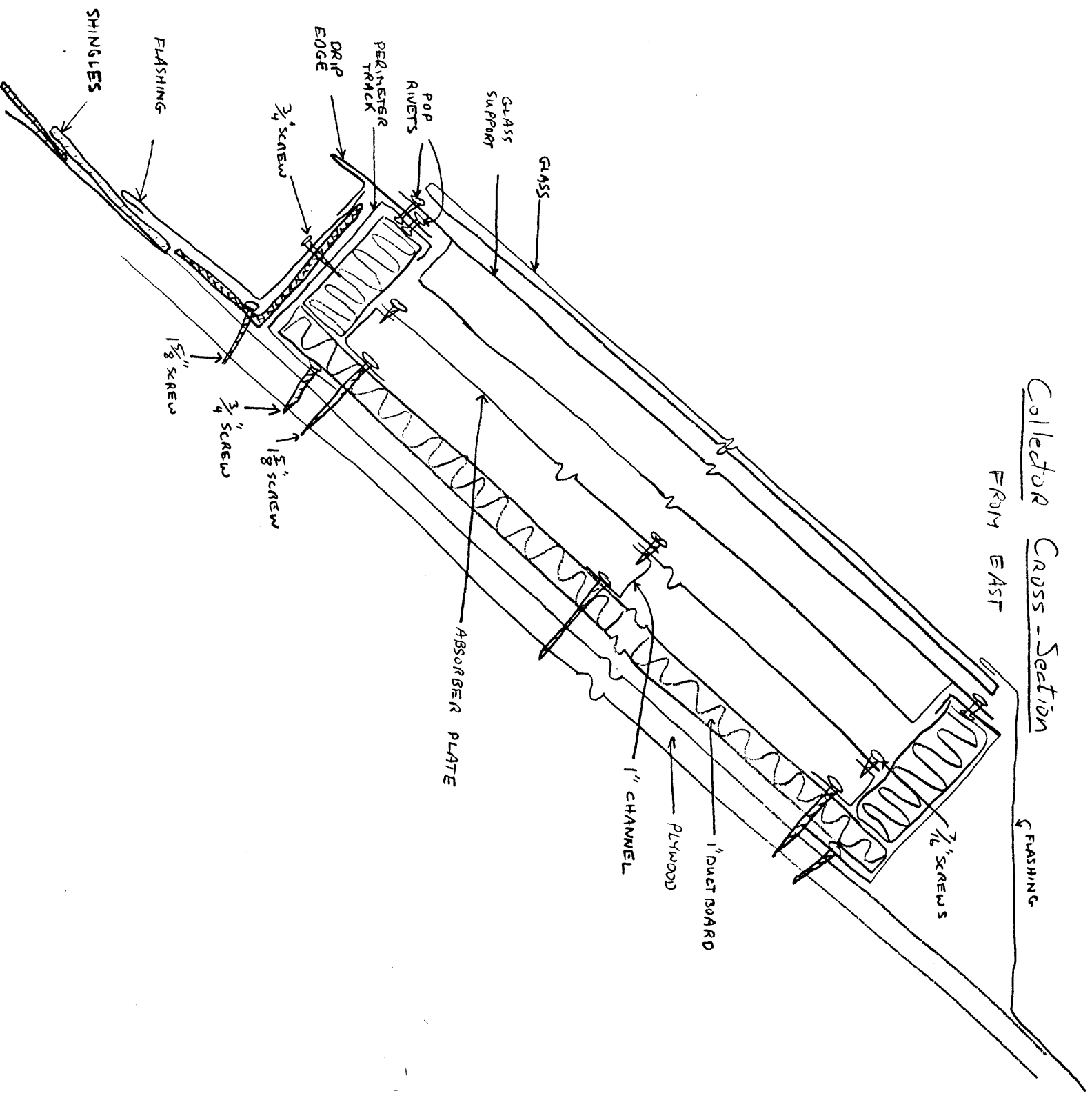
Collector Cross - Section

FROM ABOVE



Collector Cross-Section

FROM EAST



SHINGLES

FLASHING

DRIP EDGE

PERIMETER TRACK

POP RIVETS

GLASS SUPPORT

GLASS

1/8" SCREW

3/4" SCREW

1/8" SCREW

ABSORBER PLATE

1" CHANNEL

PLYWOOD

1" DUCT BOARD

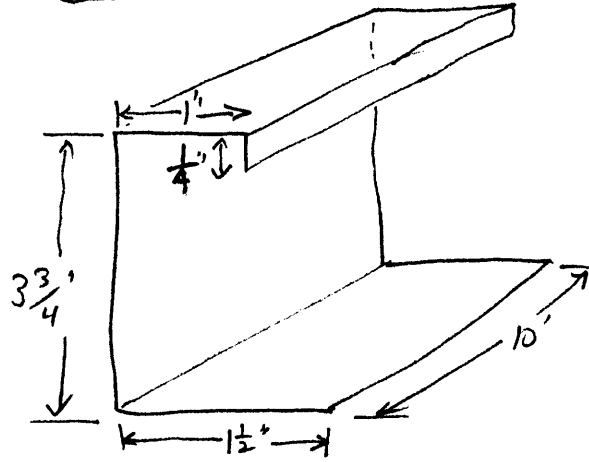
7/16" SCREWS

FLASHING

THE BEST COLLECTOR

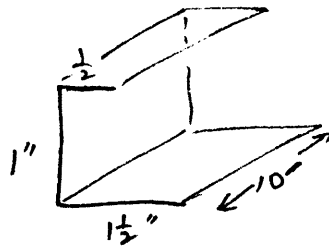
PERIMETER TRACK :

24 gauge
"Paint-lock"



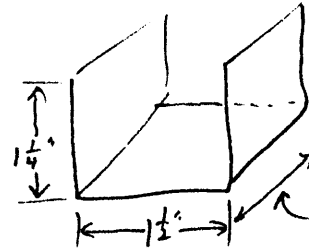
BAFFLE TRACK :

24 Gauge
Paint-lock



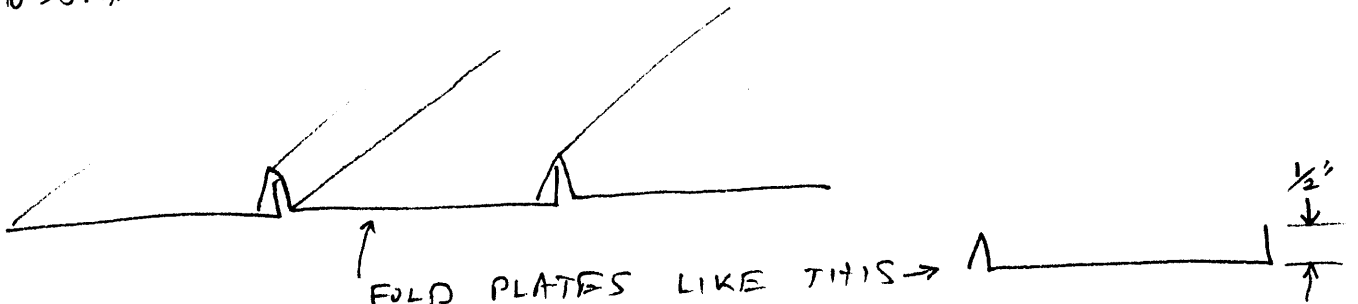
Glass Supports (a channel)

20 Gauge
Paint-Lock



77" for 76" glass
OR AS NEEDED

ABSORBER JOINTS



FOLD PLATES LIKE THIS →
ON BRAKE
FILL GROOVE WITH SILICONE,
PUT ONTO PREVIOUSLY INSTALLED PIECE, CRIMP
GROOVE CLOSED, & SCREW TO BAFFLES

BAFFLING HINT: INSTALL BAFFLE TRACK ALL THE WAY
AROUND THE INSIDE OF THE PERIMETER OF THE
COLLECTOR (AFTER DUCTBOARD), SO THAT ABSORBER EDGES
NEED NOT BE FOLDED, BUT MAY BE INSTALLED FLAT &
SCREWED AT EDGES.