

Empirical Investigations of Solar Water Heating Technology



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Over the last 15 years students and faculty at Appalachian State University have been experimenting with solar water heating technologies. We designed, constructed and tested quite a few “batch” or integral collector storage (ICS) systems and developed low cost designs that perform very well. Recently we began to empirically investigate active solar water heating systems with freeze protection.

We constructed three wedge shaped test platforms and collected enough components to put together every major type of solar water heating system. Most of the systems are designed and constructed by students taking the Solar Energy Technology course offered by the Department of Technology at Appalachian. Students have designed and built solar ovens, food and lumber dryers, space heating systems, water distillers, and greenhouses. Recently we've spent a good bit of time on PV and solar water heating technology.

For the solar water heating activity, the class splits up into three groups with approximately five students in each group. Each group designs, builds, and tests a solar water heating system. Because we have three systems being built simultaneously, we try to identify hypotheses to test and then synchronize our efforts to maintain as much validity as possible. We have compared direct (drain down) to indirect (drain back and propylene glycol), two pump indirect glycol system to a one pump indirect glycol, single wall exchanger to double wall exchanger, DC to ac, and slow to fast flow rates. This article summarizes our findings.

Methodology

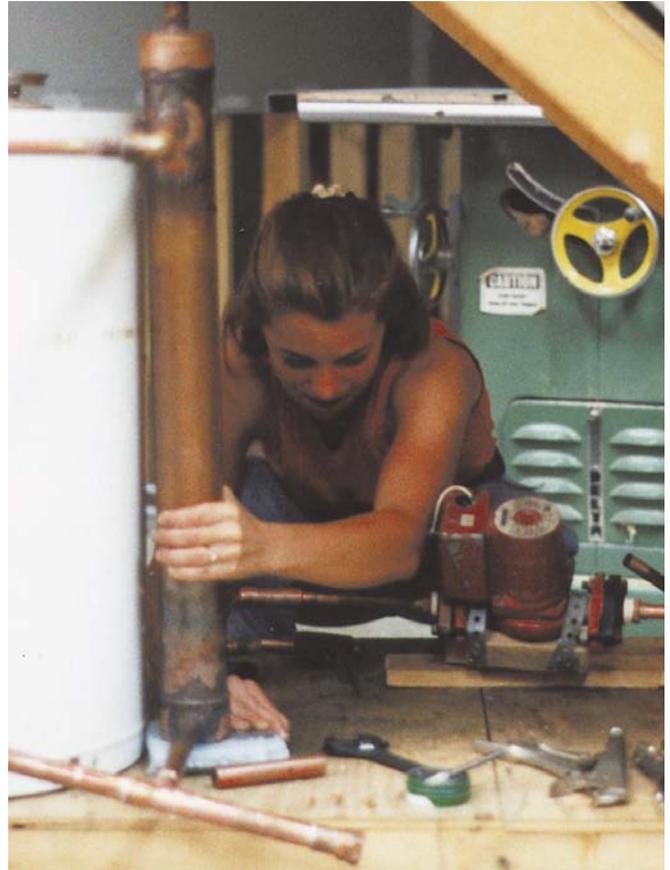
Each of the modules has identical 15 gallon storage tanks and 12 square foot collectors. The average person uses 10 to 20 gallons of hot water per day, so our small tanks would only satisfy the needs of one average person. Except for the size of the tank and collector and the length of the piping connecting them, all other components are the same as in a full size system. The collector is adequate for the storage tank capacity. In general, one square foot of collector will heat 3/4 to 2 gallons of water, depending on locale. Ours have one square foot of collector for every 1.25 gallons of water.

Using the three modules we are able to test two hypotheses at the same time. The systems are constructed by the students in our lab and then wheeled outside for testing. All 3 systems are tested side by side at the same time. The storage tanks are filled with water from garden hoses connected to an exterior hose bib. The hoses are left connected and the water storage tanks are kept pressurized throughout the testing.

Data Collecting Equipment and Procedures

We collect temperature data with an assortment of digital and analog thermometers and a four channel data logger. The analog thermometers can be slid into a well and then screwed into female pipe threads, like at the top of the storage tank. The best prices I have been able to find on these analog thermometers (\$12.70) and many other solar water heating components are from American Energy Technologies, Inc. (AET). We purchased many solar water heating components from them with good service. They have a nice catalogue and engineers on staff to answer questions. The three digital thermometers we use are Quadra-Temps from Heliotrope General. A four sensor thermometer costs \$202.87. The data logger is the XR220 Pocket Logger from Pace Scientific, costing about \$500. It is a four channel recorder capable of measuring temperature, humidity, pressure, and ac current. It operates on a 9 Volt battery and the data can be transferred to any MS-DOS compatible PC running Pocket Logger software. The data can be easily charted and/or imported into spreadsheet and statistical software packages. For flow measurements we use both Taco and Blue White flow meters. The Taco meters are no longer available. The Blue White meters cost about \$50. We use the three Quadra-Temps, analog thermometers, and flow meters to manually collect temperatures as often as possible during the day. The Quadra-Temp sensors are attached to the copper piping with hose clamps or tape. Normally we are interested in the four connections to the heat exchanger, if one is being used. The data is collected every hour or whenever convenient and is recorded on paper. The data can be transferred to computer for analysis and charting. Recently we began using the four channel Pocket Logger for data collection. Its sensors can be taped to the piping and it can automatically collect data as often as desired. This data can be easily charted and/or statistically manipulated.

We also measure the average tank temperature at the end of the day by shutting off the water supply to the storage tank, opening a drain valve at the bottom of the tank and a valve at the top of the tank (to let air in), and holding an analog thermometer in the stream of water as it exits the tank. Every 30 seconds we record the temperature until the tank empties. The temperatures



Above: Installing an AET single wall heat exchanger.

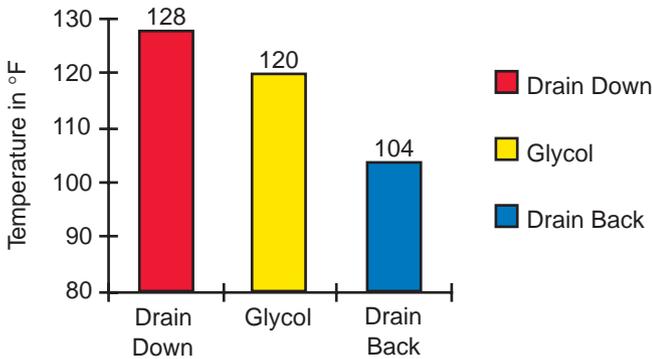
are then averaged. It is not a perfect system, but it works well enough. There is no electric backup connected to the systems we have tested and also no water is drawn from the tanks during the test period.

Direct vs. Indirect

The direct system circulates potable water through the solar collector. It consistently performs the best in our tests. Chart 1 shows the average tank temperatures for all test days for three of the major types of active solar water heating systems in use in the US today. It compares a direct system, an indirect glycol system with a natural convection potable water loop and a single wall heat exchanger, and an indirect drain-back system with a home made drain back tank. For freeze protection in the direct system we have been using drain-down valves manufactured by Heliotrope General (Figure 1). They manufacture both an ac controlled valve (HG-Spool) and a new DC PV controlled valve (Solar-Sidebar). We have used them both. The valve opens in the morning with sufficient solar insolation and a small ($\leq 1/40$ th HP) stainless steel or bronze pump is turned on at the same time and pumps pressurized potable water into the collector. When the insolation decreases sufficiently the valve closes and prevents

Water Heating

Chart 1: Direct vs. Indirect average daily tank temperature in °F



any additional flow into the collector. At the same time the pump turns off and the valve allows the water existing in the collectors and piping to drain out. The ac valve requires a special controller (DTT-74 or DTT-794) and two 10 K Ω thermistors, which are available from Heliotrope General. The DC PV controlled Solar Sidebar uses a 10 Watt PV module. All the major components needed are included and assembled. The system only needs to be attached to the collector and storage tank. No controller is required. It is a nice unit, and is quick and easy to install. Heliotrope has recently improved the drain-down valve and offers a limited ten year warranty on this product.

The indirect systems have both a collector loop and potable water loop. The loops flow in opposite directions and the fluids in these loops never mix. The potable water loop picks up the heat from the collector loop through a heat exchanger, which is nothing more than a copper pipe or pipes inside another pipe or container. The indirect systems we have explored are the drain-back and the propylene-glycol anti-freeze.

Drain Back System

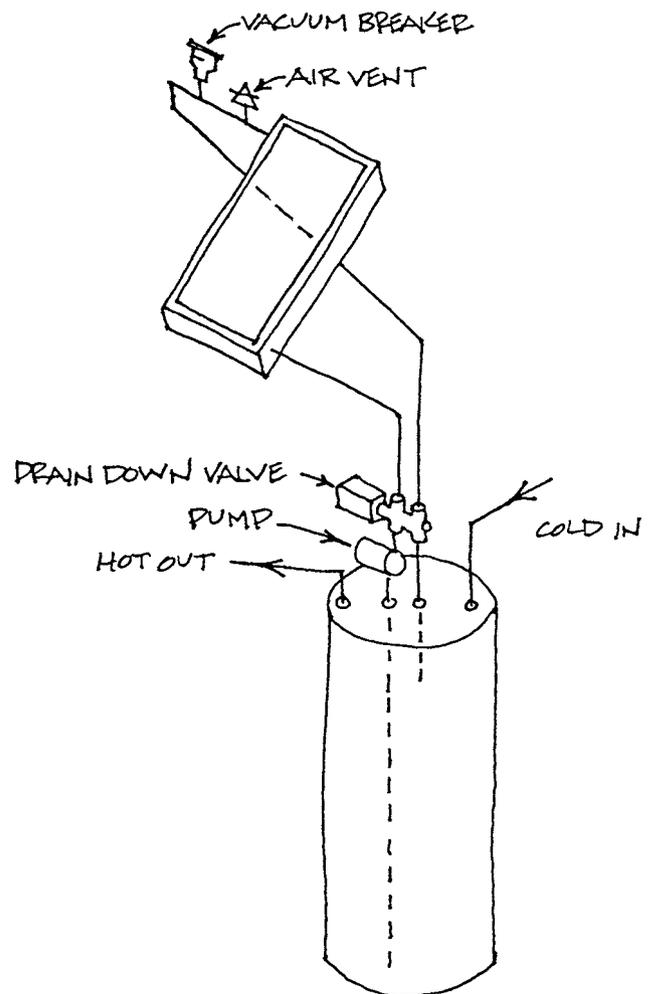
Our home built drain back tank is a 16 x 16 x 16 inch steel box with a 10 foot coil of 1/2 inch copper pipe inside (Figure 2). The potable water is pumped with a small ($\leq 1/40$ th HP) stainless steel or bronze pump through the copper coil, picking up heat from the collector water around it. Inside the steel box and around the heat exchanger is the collector water, treated with a rust inhibiting solution of sodium-hydroxide, trisodium phosphate, morpholine, and sodium dichromate (from Hicks Water Stoves & Solar Systems), which gets pumped up to the collectors by a second larger and usually cast iron (1/12 HP) pump whenever they are hotter than the water in the bottom of the tank. The two pumps are controlled by a Heliotrope General (DTT-84) differential controller and two 10 K Ω thermistors. This type of system is very common in North Carolina, especially in larger 500 or

750 gallon versions providing space heating to the house as well as hot potable water. These systems can perform very well. However, our system did not (Chart 1). The weaker performance is probably related to the increased quantity of fluid this design has to heat and inadequate insulation of the drain-back tank.

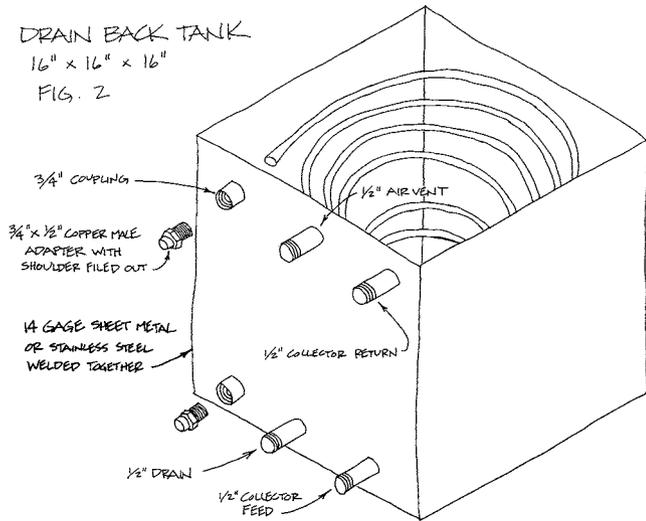
Glycol Systems

Recently we have focused our attention on indirect propylene glycol systems. These systems are simple, reliable, and inexpensive. We have been using external heat exchangers which connect directly to either an electric water heating tank (see photos) or a separate solar storage tank that would be plumbed in series with a gas fired water heating tank. These external exchangers cost a lot less than a storage tank with a built in exchanger, can eliminate the necessity of purchasing a new solar storage tank for someone who wants to add solar to an existing electric hot water heating system, and provide more flexibility in choice of storage tank size. An external heat exchanger can be

**DIRECT DRAIN DOWN SYSTEM
FIG. 1**



DRAIN BACK TANK
16" x 16" x 16"
FIG. 2



Right: A complete system minus the collector.



purchased for about \$100 (see photo). Special solar storage tanks with built in heat exchangers can be purchased, but they are only available in a small number of sizes and are quite expensive. AET offers only one tank with a built in wrap-around heat exchanger. It is an 80 gallon tank with copper coil wrapped around the outside of the bottom half of the tank. Insulation is wrapped around the tank and exchanger. It costs \$576. Shipping could add another \$100 to the cost. One can purchase a regular 80 gallon electric water heating tank for about \$230 at a local building supply center and other sizes are available for less. Adding an external exchanger brings the cost up to \$330. So for \$330 one can get essentially the same equipment as the 80 gallon tank with a wrap-around exchanger, with a delivered cost over \$600.

Figure 3 shows a basic schematic for an indirect system with an external heat exchanger. The photos

also show a similar indirect system, configured slightly differently than Figure 3. The system depicted has a ball valve where a check valve would normally be placed. I did not feel a check valve was needed because the collector was mounted on the ground below the elevation of the storage tank and therefore should not reverse thermosiphon at night. The system in the photo also has an extra air vent installed in the collector supply line, several analog thermometers installed, and a slightly different expansion tank position. The storage tank, exchanger, and the pipes to the tank and collectors should be well insulated. Low flow shower heads should also be installed.

A 50/50 mix of water and propylene glycol (boiler anti-freeze from Camco Manufacturing) is pumped into the system. Most full size systems hold 6 gallons or less. Some glycols come already diluted with water. Make sure you read the label. A 4 x 10 foot panel holds about 1.5 gallons. The boiler drain valves on either side of the check valve enable filling, pressurizing, and draining the system (Figure 4). We fill and pressurize to about 15 psi with a Teel drill driven pump (model 1P866). The pressure should be a little more than the pressure or static head that the fluid will exert from the elevation difference between the tank or exchanger bottom and the collector top, 1 psi for every 2.25 feet or .44 psi per foot difference. 15 psi equals 33.75 feet of static head, and is more than our modules have.

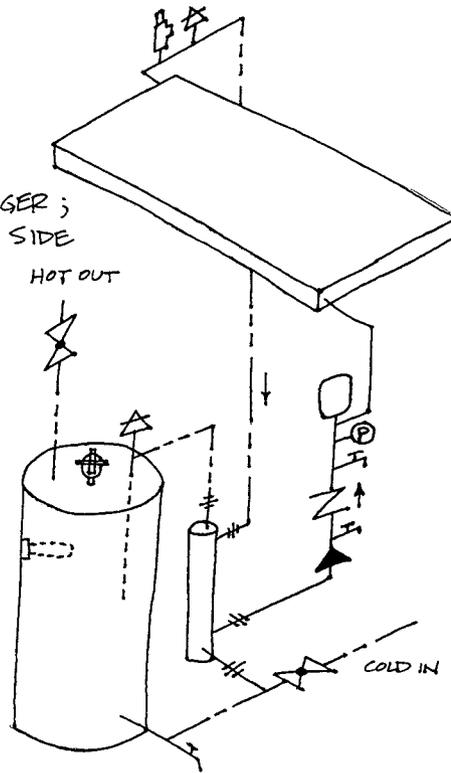
Left: Some serious problem solving going on here.



FIG: 3
ACTIVE INDIRECT
GLYCOL SYSTEM,
WITH SINGLE WALL
EXTERNAL HEAT EXCHANGER;
PUMPED ONLY ON GLYCOL SIDE

LEGEND

- COLD
- HOT
- ▲ PUMP
- I HOSE BIB
- Z CHECK VALVE
- ⊕ PRESSURE GAUGE
- △ AIR VENT
- ⊘ BALL VALVE
- ≡ UNION
- PRESSURE TANK
- ⊞ ADJUSTABLE PRESSURE RELIEF VALVE
- ⊞ P/T RELIEF VALVE



When the system is operating (Figure 3) the glycol mixture is pumped with a small ($\leq 1/25$ HP) cast iron, bronze, or stainless steel pump from the bottom of the exchanger through a check valve and fill/drain assembly and into the bottom of the collector. The check valve prevents reverse thermosiphoning at night or on cloudy days and needs to be pointed the correct way. An expansion (pressure) tank and pressure gauge are also depicted in this side of the collector supply loop, but could be installed anywhere in the loop. The expansion tank (normally 2 gallon) has an air filled bladder which gets compressed by the expanding hot fluid in the collector loop. This protects the system components from excessive pressure. The pressure in the expansion tank should be measured before filling the system and if needed, adjusted so that it is close to the static head pressure. They normally come precharged with 12 psi, which would be good for most situations. If a flow meter is desired it would normally be positioned vertically in this side of the supply loop. One should also install a ball valve below or above the flow meter so that the flow rate can be controlled. Some flow meters have valves built in.

The glycol fluid exits the top of the collector in the corner diagonally opposed to the supply corner in order to maintain a balanced flow through the collector. The heated glycol then passes by a 150 psi air vent installed

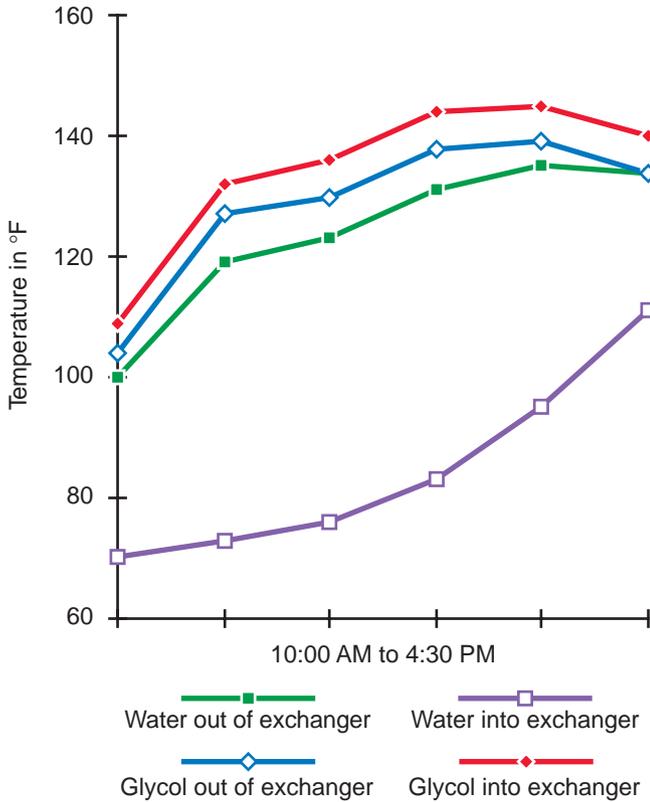
vertically at the high point of the system and an adjustable pressure relief valve set at about 90 psi. This is a little less than the expansion tank bladder's maximum psi rating and should protect all components if for some reason the pressure would rise that high. We have had some "pop off" problems with the pressure-temperature valves commonly used on water heating tanks and like to use the adjustable pressure relief valves from AET.

Potable water is normally taken from the bottom of the tank at the drain opening. The drain is re-installed in a tee fitting at the opening. This water from the bottom of the tank can be either pumped or naturally convected through the exchanger. It flows in the opposite direction of the glycol. The hot water from the top of the exchanger is returned either at the side of the tank or in the top of the tank. This could be where the temperature/pressure relief valve is

installed or in the cold in port at the top of the tank. The P/T relief valve could be removed and installed with the return water in a tee fitting or installed somewhere else in the potable loop. If the cold in port is being used for returning the solar heated water to the tank, then the cold water can be delivered to the tank in the drain port at the bottom of the tank and the cold water dip tube can be taken out and cut to reduce it's length so that water is delivered about 10 inches below the electrical element. AET recommends perforating the dip tube all up and down it's length. An air vent should be installed at the highest point of the hot water return line. This is especially important for systems that naturally convect the potable water through the exchanger. If the system has only one tank with electric elements then the bottom element should be disconnected. In this kind of system the flow rates of the potable water should be slow (less than .5 gpm) to avoid excessive mixing of the water and the temperature of the return water should be close to the thermostat setting of the element. The flow rates will be slow if the potable loop naturally convects.

Chart 2 shows temperatures from a sunny June day for each to the heat exchanger. The temperatures are for a system similar to the one depicted in Figure 3 which naturally convects the potable water through the exchanger. The average temperature of the water in the tank at the end of the day was 130° F.

Chart 2: Pump Indirect Glycol external heat exchanger temperatures in °F



We examined several configurations of indirect glycol solar water heating systems. We compared one pump systems to two pump systems. The one pump systems move the non-toxic propylene glycol fluid through the collector loop and allow natural convection to circulate the potable fluid through the exchanger. The two pump systems have pumps on the potable as well as the collector loop. We compared single wall exchangers to double wall exchangers, slow flow rates to fast flow rates through the glycol loop, and PV powered and controlled DC circulating pumps to ac pumping systems with differential controllers.

One Pump vs. Two

Most indirect systems in North Carolina have two pumps, one on the collector loop and one on the potable water loop. The pumps used in these indirect systems, which are under pressure, only have to overcome the dynamic head or pressure due to the resistance of the fluids flowing through the loops. Therefore, they can be pretty small, often a 1/40th HP pump or smaller is adequate, although a 1/25th HP is typical. A small ($\leq 1/40$ th HP) bronze or stainless steel pump should be used on the potable loop. As mentioned before, the glycol loop pump can be cast iron, although bronze or stainless are reported to last

longer. Two 5 Watt DC pumps (available from Ivan Labs, AET, or AAA) could be used and both could be powered by a single 10 Watt PV module. Chart 3 shows how this system heats the potable water in the tank. The storage tank water gets mixed quickly with 2 pumps, eliminating temperature stratification within the tank. In our tests this slowed the production of hot water available in the top of the tank, but produced a higher average tank temperature by the end of the day.

A one pump system that thermosyphons on the potable water side will maintain a temperature stratification in the water tank (Chart 4). This improves the efficiency of the collector and results in quicker water heating.

Chart 5 shows a comparison of these two system types. On 5 test days the double pump system produced hotter average tank temperatures at the end of the day by 5 to 9.5°F or about 6%. However, when one considers the extra initial cost (about \$100) and the operating cost (about 200 Watt-hrs/day in summer for a 1/40 HP pump) the small increase in performance may not be worth it. With a one pump system be sure to have a properly functioning air vent at the highest point of the solar heated water return line and keep things as hydrodynamic as possible. Don't put a check valve or flow meter in the potable water loop. Use 3/4 inch piping and a minimum of fittings. If delivering the hot water to the top of the tank by natural convection, keep the height of the delivery pipe as close as possible to the top of the tank.

Chart 3: Two Pump Glycol System water tank temperature in °F

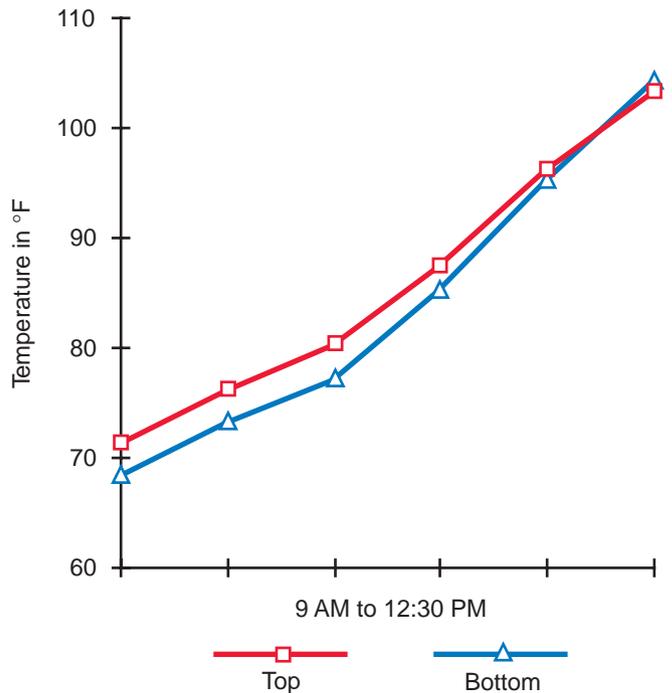


Chart 4: One Pump Glycol System
water tank temperature in °F

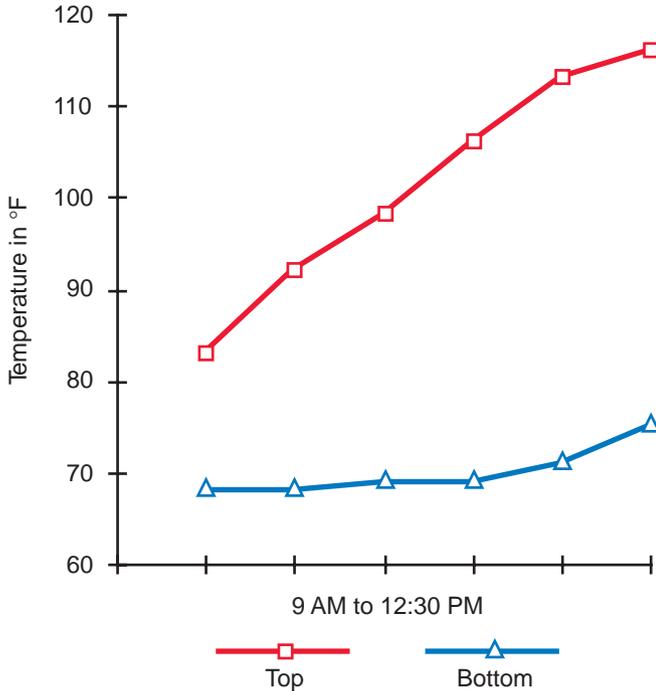
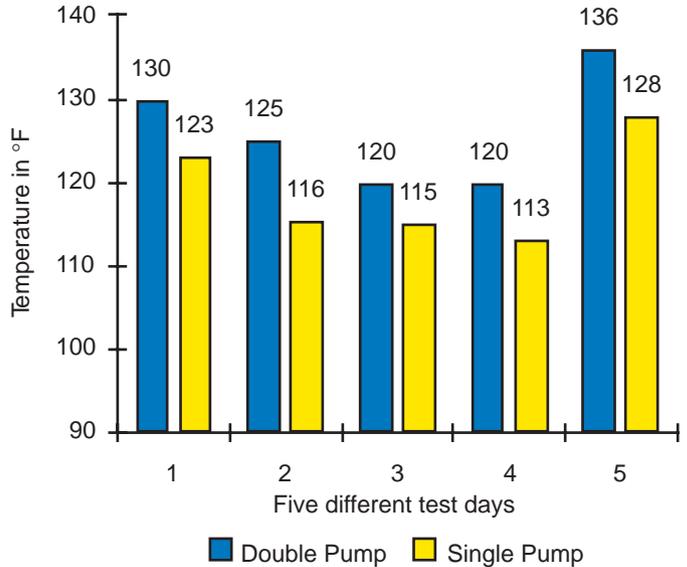


Chart 5: Number of Pumps
daily average tank temperature



Single Wall vs. Double Wall Heat Exchangers

Single wall exchangers have one layer of copper between the glycol fluid and the potable water. This is a material and energy efficient design. However, if a leak develops the glycol fluid could contaminate the potable water. This should not really be a major problem because propylene glycol, unlike the ethylene glycol used in most automobile radiators, is not toxic. Propylene glycol toxicity has been reported only rarely and in unusual circumstances, such as intravenous injection. It is used in medicines, cosmetics, and food products as an emulsifying agent. And even if it was a little toxic, the hot water would not normally be drunk, the quantity is relatively small, and the problem would be easily identified by monitoring the pressure gage. Also, the house water pressure normally exceeds the

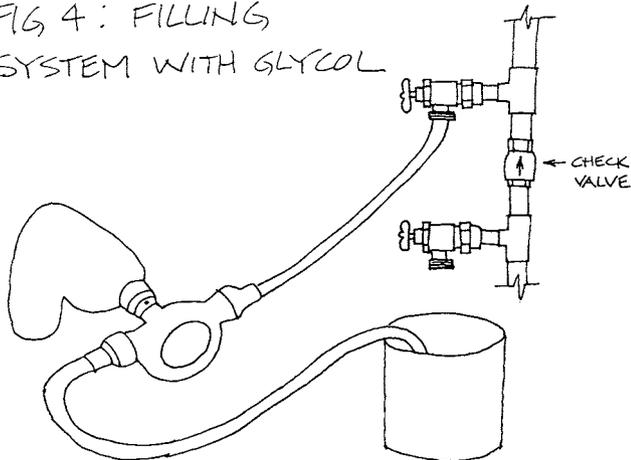
pressure in the collector loop, which would inhibit leaking of the glycol into the potable water.

A growing number of consumers are concerned about exposure to toxic materials in the home and seem to be more comfortable with the double wall concept. Some state plumbing codes require double wall exchangers.

The double wall exchangers provide an extra margin of safety in case a leak develops in the anti-freeze loop. There are two layers of copper between the glycol fluid and the potable water. But do they sacrifice a lot of efficiency by emphasizing safety? This was a question we wanted to try and answer.

The double wall heat exchanger we used was purchased from AAA Solar. They have a great catalogue with a lot of good information about designing solar water heating systems and many good products for sale. Their double wall exchanger that we tested is called the Hot Rod. They have a new improved unit called the Quad Rod which we have not tested. The commercial single wall exchanger we tested was purchased from AET. Both companies offer a variety of sizes. We used the smallest and least expensive, a 3 foot Hot Rod which cost \$87.67 and a 24 inch single wall exchanger from AET costing \$95.

FIG 4: FILLING SYSTEM WITH GLYCOL



A single wall exchanger can be easily constructed (Figure 5) by placing a 1/2 inch copper pipe inside a 3/4 inch copper pipe with 1/2 x 3/4 x 3/4 inch tee fittings at each end. I don't know what the ideal length would be, but for a system that will naturally convect on the potable side I would make the exchanger about the same length as the tank height. The 1/2 inch copper



Above: A DC system without check valve.

tubing should be longer than the 3/4 inch tubing so it can be slid through the 1/2 inch ends of the tee fittings. The shoulder inside the 1/2 inch end of the tee fitting needs to be filed down a little. Clean, flux, and solder the two fittings and the tubing together and that's all there is to it. We have built and successfully used one of these but have not compared it to store bought units.

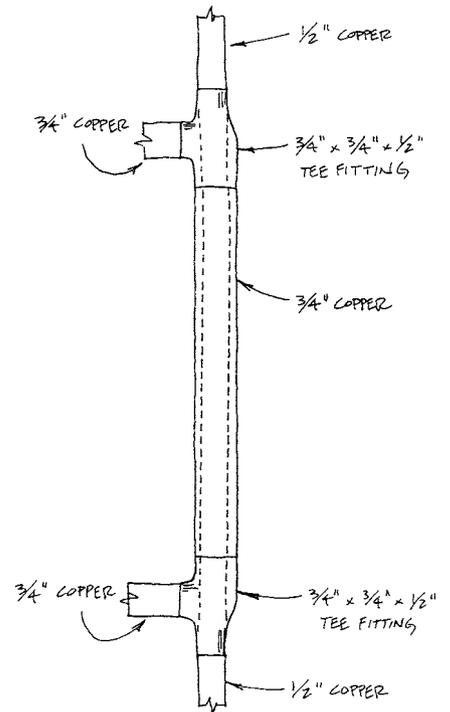
Chart 6 illustrates the results from 8 test days comparing the AET single wall exchanger to the AAA Hot Rod double wall exchanger. The average tank temperatures were from 1 to 7° F higher in the system using the AET single wall exchanger, a difference of about 3%. Both systems were using a pump only on the glycol loop. One of the most surprising results of our recent solar water heating investigations was how well the Hot Rod double wall exchanger performed. It exhibits good performance, universal code compliance, and extra safety. It also costs less than AET's. Their new Quad Rod may be even better.

Flow Rates

How fast the fluids should flow through a solar water heating system is a question anyone who installs a system will ask themselves. The answer depends on whether the system is a direct or indirect and, if indirect, what loop is being considered. Flow rates should be slower in direct systems and on the potable loop of an indirect system connected to an external heat exchanger. The flows in an active system can be regulated by a flow meter and ball valve or preferably by a properly sized pump. The Florida Solar Energy Center recommends 1/2 gpm for each 40 square feet of panel area, or .0125 gpm per square foot of collector area. ASHRE recommends .03 gpm per square foot of collector area for maximum collector performance. Our most recent test examined the performance of two single pump indirect systems with single wall external heat exchangers. One of our systems had approximately 1/2 gpm flow and the other 2 1/2 gpm through the collector loop or .04 and .20 gpm per square foot of collector. Both rates examined were faster than recommended.

Our Taco flow meters made it difficult to measure below .5 gpm so we didn't go below this flow rate. The potable water circulated slowly through the exchanger by natural convection and was not measured because an affordable meter would inhibit the natural convection flow and not be sensitive enough. The flow rates examined did not seem to have much affect on performance. There was only a 1° F difference favoring the 2.5 gpm system. I believe this difference could easily be explained by some other unaccounted difference in the two systems. A recent masters thesis by Thornbloom (1992) found that flow rates through the collector loop didn't significantly affect performance. Slower flow rates don't require as

FIG 5:
HOME MADE HEAT EXCHANGER



large a pump. The smaller pumps cost less to purchase and operate.

Research demonstrates that slow flow rates (around .25 total gpm or .01 gpm per square foot of collector area) on single tank direct systems improves performance by 20 to 30%. There is less mixing of the water in the tank. The water stays stratified and the collector feed water at the bottom of the tank stays cool longer. This cooler water more effectively picks up collector heat.

DC vs. ac

DC pumps are available for solar water heating systems that require as little as 5 Watts of power. We are currently using El-Sid pumps from Ivan Labs Inc. They have the best prices I have found and 3 models are available. The pumps are capable of 1.7 to 3 gpm at full sun (317 Btu/hr or 1000 Watts per square meter). They all use the same March 809 bronze pump, but have different size drivers; a 4-5 Watt, 5-7 Watt, and a 10 Watt. We used the largest driver with a

Water Heating

Chart 6: Exchanger Type
daily average tank temperature in °F

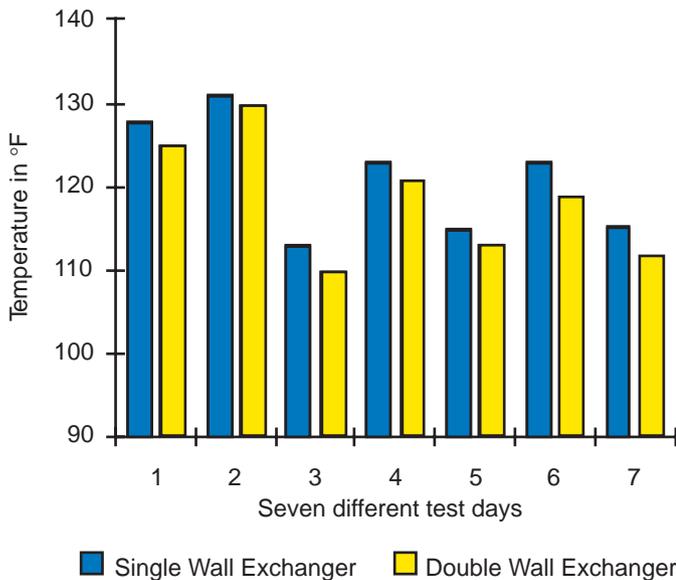
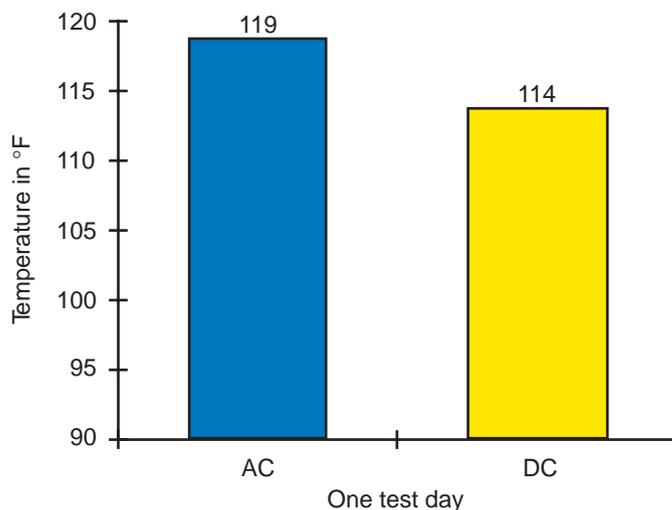


Chart 7: AC vs. DC
daily average tank temperature in °F



Siemens M10 10 Watt module for this test. It was purchased from Hutton Communications for \$128.00. A 5 Watt module such as the Solarex SA-5 is all that is required for their smallest pump. This system design eliminates the need for a controller. We have collected data on three different days and our single pump ac systems have consistently out performed our "identical" DC systems by a small amount. Chart 7 shows the greatest difference observed in the average tank temperatures at the end of a test day. I think the slight performance differences may not be related to the ac/DC variables but to slight differences in our elderly collector efficiencies. We need to mix our components up and try this again or test our collectors.

When using a PV powered and controlled DC pump, use a Zomeworks floating ball check valve in the return piping (from AAA) or a vertical check valve with the spring removed in the supply piping. The AET check valves can be screwed apart and the spring easily removed. The flow path should be as hydrodynamic as possible with 3/4 inch copper tubing and a minimum of turns and fittings. Make sure a properly functioning air vent is set at the highest point in each loop.

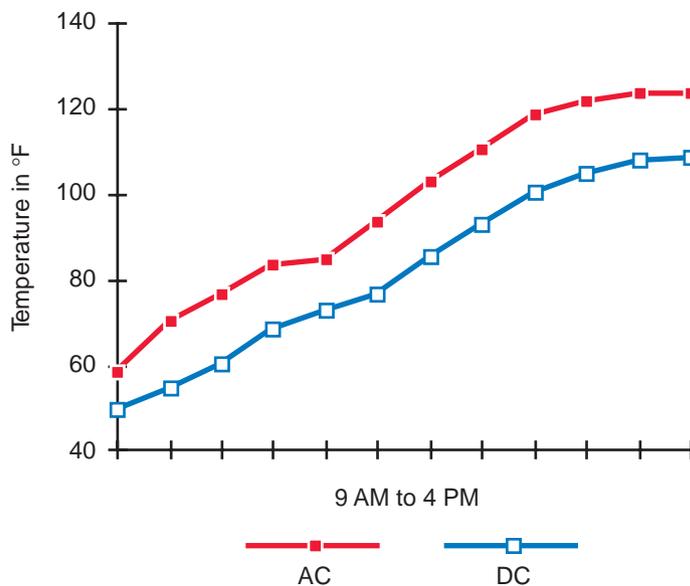
Cost Comparisons

The initial cost of a solar water heating system is probably the most important consideration for someone considering purchasing a system. Fortunately for us in North Carolina we can take advantage of a 40% state tax credit, the most generous in the country. Our empirical research shows that all the common system designs work well if properly installed and the differences in performance between system types is not

that significant. The drain back system was the only really poor performer and I think future tests with a larger system and better insulated drain back tank will show more comparable performance. Probably the most important aspect of system performance is getting the correct square footage of collector for the quantity of water one wants to heat. This varies depending on geographical location and system type.

I have compared the costs of the systems discussed in this article in Chart 9. I excluded the collector cost, storage tank cost, the cost of piping to and from the collector, pipe insulation, and fittings. They are approximately the same for all similarly sized systems

Chart 8: AC vs. DC
top of tank temperature in °F



and would add about \$1000 (if all new components were used) to the cost of a single panel system. The costs of piping, insulation, and fittings would be approximately \$300 and the same for all systems. A tank is about \$200 and a new 4 x 10 foot collector about \$500. All material costs used to construct Chart 9 were taken from AET, AAA, Heliotrope, or local vendors and were the best prices I could get as an educator and part-time designer and installer.

The best price I have found on new collectors is about \$12.50 per square foot from AET and Sunquest. If they have to be delivered add up to \$2.50 extra per square foot. AET advertises a 4 x 10 foot black chrome collector for \$507.00. This equals close to 50% of the total material cost. There are a lot of used collectors on the market. Many become available from people who are having their roofs re-shingled. I have purchased perfectly good collectors for about \$1.25 per square foot or in some cases get them for nothing.

As Chart 9 depicts, the glycol systems are less expensive than the others. The material cost for the cheapest is \$339. Adding \$300 for piping, fittings, and insulation the total cost is about \$638, minus collector



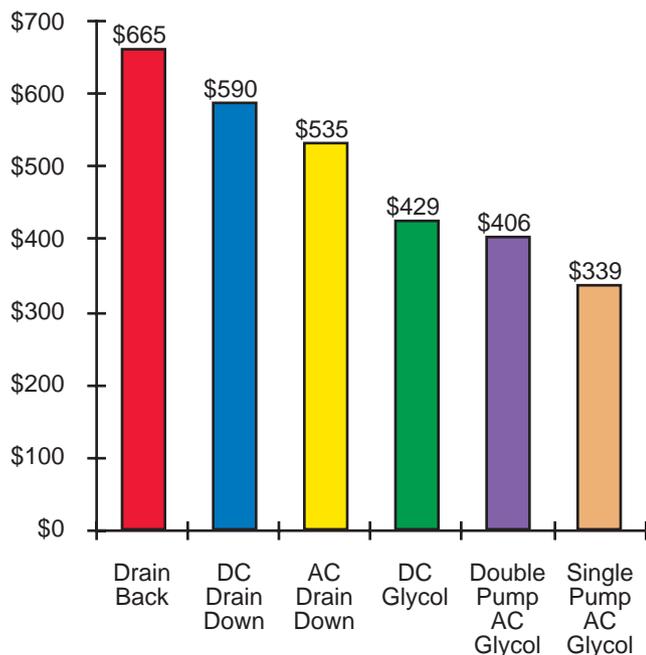
Above: Appalachian students just doing it.

and storage tank. This system could pay for itself if electricity were used for water heating in 3 to 4 years. A reasonable total cost for a single panel installed system with all new components including a tank would be \$2000 (\$700 for installation and \$1300 for materials). With a 40% tax credit the installed price for a new system would be about \$1200. This system, if properly installed, will provide between \$200 and \$300 worth of hot water, at current electrical rates, per year and will last for 20 years or more. The system cost could be reduced by using a "second hand" collector, a "snap disc switch" instead of a differential controller, and by using a home made heat exchanger. We have tested snap disc switches and they seem to work well. They are thermally actuated switches that turn on at 110° F and off at 90° F and are available from AAA for \$28.

The drain back system was the most expensive in my analysis. It requires a drain back tank which cost \$354 from AAA and also two pumps. The collector loop pump normally needs to be larger and more expensive to overcome the static and dynamic heads in the unpressurized drain back design.

The labor for installation is a consideration and can equal or exceed the cost of materials. A ground mounted panel, PV controlled, single pump indirect glycol system with an external heat exchanger took me 50 hours to install. It was my system with these components and I was working alone. I could probably do it faster the second time. The Heliotrope drain down direct systems would be less time consuming to construct, especially with the new Solar Sidebar.

Chart 9: Cost Comparisons
excluding collector, tank, and piping





Above: Completing the connections between the exchanger and collector.

Conclusion

Solar water heating technology is affordable, works well if properly designed and constructed, and the components are readily available. The direct solar water systems have been the best performers in our tests. The average tank temperature for the direct systems was 6% higher than the single pump, single wall exchanger, glycol systems tested; and 19% higher than the drain back system. The major drawbacks of the direct system for colder climates are freeze protection and possible clogging of collector tubing if potable water has high mineral content or is "hard". The Heliotrope HG-Spool and Solar Sidebar drain-down valves promise reliable freeze protection and the superior performance of the direct system.

The indirect glycol systems with external heat exchangers seem to be the best value and offer excellent performance and reliability. In our tests on indirect systems with external heat exchangers, two pumps produced about 6% hotter water than a one pump system. The AET single wall exchanger produced

3% hotter water than the AAA double wall, the collector flow rates examined did not significantly affect system performance, and on the three days we compared ac to DC, the ac system produced 4% hotter water than a PV powered and controlled DC system. Future projects will continue to compare the PV powered and controlled DC pumping systems with ac systems and will compare AAA's Quad Rod exchanger and our home made exchangers to those already tested. Many other questions can and will be addressed.

Designing and building solar water heating systems is a great educational activity for students, filled with problem solving and hypothesis testing situations. Students found this activity to be enjoyable, challenging, and a great learning experience.

Access

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"Solar Water and Pool Heating: Design and Installation Manual (1992)", Florida Solar Energy Center, 300 State Road 401, Cape Canaveral, FL 32920 • 407-783-0300

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