FLORIDA SOLAR ENERGY CENTER

Creating Energy Independence Since 1975

Solar Swimming Pool Heating Systems

A Research Institute of the University of Central Florida

Solar Pool Heating Systems

- **Module: System Components, Installation and Operation**
  - illustrates and describes the physical elements of solar pool heating systems. Guidelines for component and system installation are provided.

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- Task for which solar energy is admirably suited.

- Desired pool temperatures range from 72°F to 85°F
  - only slightly above the winter daytime mean temperature in most of Florida.
  - 80° F is norm
- Allows installation of simple , highly efficient and inexpensive solar systems

- Backbone of the solar industry in Florida
  - 80% of solar production is from solar pool application

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Economics

- Solar swimming pool heaters save money
- Represent an outstanding example of a use of solar energy that is economical today
- Everyone benefits from their use
  - the pool owners reduce their monthly pool heating expenses
  - the installation contractor can make an acceptable profit
  - our nation has more gas and oil for critical needs.

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Heat Loss Mechanisms – Evaporative Losses

- Familiar to anyone who has ever stood in a breezy spot, wearing a wet bathing suit
- Evaporation cools the surface of a swimming pool in the same way
- The rate of evaporation from a pool surface is dependent upon wind velocity, air temperature, relative humidity and pool water temperature
- Standing in the wind or in front of a fan accelerates evaporation, making a person feel cooler
- On warm, muggy days with high relative humidity, evaporation is inhibited and it is hard to stay comfortable

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Heat Loss Mechanisms – Evaporative Losses

- Warm water evaporates more rapidly than cool water
- Up to 70 percent of a swimming pool's heat energy loss results from evaporation of water from its surface
- Evaporative losses are directly proportional to wind velocities at the pool surface and are higher from warm pools than from cooler pools
- Most of the heat loss from a swimming pool is caused by evaporation of water from the surface
  - every effort should be made to reduce the evaporation process.
  - Air temperature and relative humidity (both of which influence the rate of evaporation) are beyond our control

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Heat Loss Mechanisms – Convective Losses

- Occur when air cooler than the pool water blows across the pool surface
  - The layer of air that has been warmed by contact with the water is carried away by the wind and replaced with cooler air – a process that continues as long as the air is in motion.
  - Anyone who has been exposed to a cold winter wind knows that convective heat loss can be substantial and that it increases with the wind's speed.
- Detailed observations show the heat energy lost from a pool in this fashion is directly proportional to the wind speed at the surface – doubling when the air velocity doubles.

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Heat Loss Mechanisms – Convective Losses

- In Florida, as much as 20 percent of a swimming pool's thermal energy loss is caused by convection
- Pools openly exposed to the wind will lose proportionally more energy than will shielded pools, windbreaks are desirable to reduce wind speed at the pool surface
- Windbreaks such as hedges, trees, solid fences, buildings and mounds should be placed so as to shield the pool from cool winds
- The direction of prevailing winds for any given month is available from your nearest weather station. Remember that cool winds come from the N, NE or NW in Florida

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Heat Loss Mechanisms – Radiative Losses

- Swimming pools radiate energy directly to the sky, another important energy loss mechanism
- Under normal conditions, clouds, dust and Florida's high humidity raise the year-round average sky temperature to only about 20°F less than the air temperature
- Even with a small difference in temperature between the pool surface and the sky, radiative losses may exceed 10 percent of the total swimming pool energy losses

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Heat Loss Mechanisms – Conductive Losses

- Since a swimming pool is in direct contact with the ground or air around it, it can lose heat energy by conduction
- The amount of energy transferred even from above ground pool walls to the air is quite small compared to the amount lost from the pool surface to the air
- Dry ground and concrete are relatively good insulators, so the energy lost through the sides and bottom of an in-ground pool is also small
- In fact, much of the energy conducted into the ground during the day is recovered when the pool temperature drops slightly during the night. In general, conductive losses through the walls of in-ground pools may be ignored

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Heat Loss Mechanisms – Conductive Losses

- Pools immersed in groundwater that is influenced by tidal motion will lose an increased amount of energy through their walls
- Heat flows from the pool to the ground-water surrounding it
- As the groundwater is moved by the tides, it will be replaced periodically by cooler water
- The quantity of heat loss in this situation is higher than for pools in dry ground and is not negligible
- This loss is still low compared to losses through evaporation, convection and radiation

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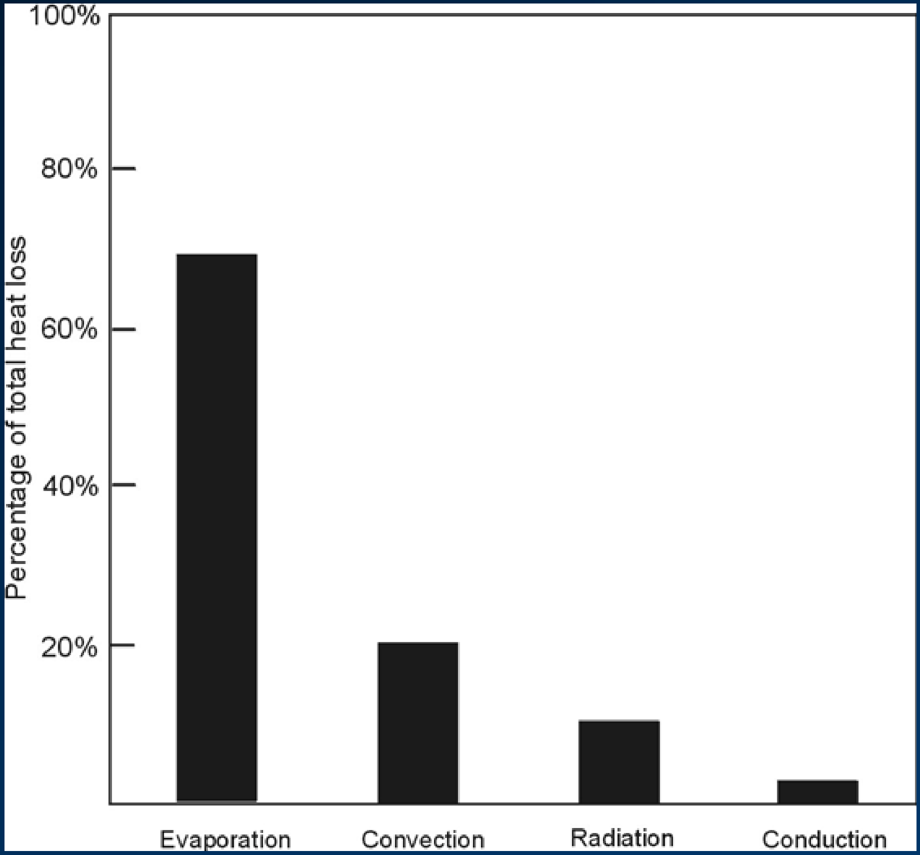
Heat Loss Mechanisms

- Graph summarizes the principal heat loss mechanisms for in ground pools and shows their relative magnitude.



Swimming pool heat loss mechanisms

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Passive Pool Heating

- The use of passive techniques is the simplest and most cost-effective method of keeping swimming pools warm
- A passive solar system is one in which the heat flows naturally – without the assistance of pumps and fans
- Every effort should be made to incorporate the following three features in new pool construction to minimize the expense of supplementary energy for pool heating:

  1. Place the pool in a sunny spot

  2. Reduce the wind velocity at the pool surface with suitable windbreaks

  3. Use a pool cover when the pool is not in use to minimize evaporation losses

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Passive Pool Heating

- Swimming pools themselves are very effective solar energy collectors
- The water absorbs more than 75 percent of the solar energy striking the pool surface
- If possible, locate the swimming pool so it receives sunshine from about three hours before until three hours after solar noon
  - During this time period, the sun's rays travel through a relatively short atmospheric path and thus are at their maximum intensity
  - Additionally, there is less tendency for the sun's rays to be reflected from the pool surface during midday than during early morning and late afternoon, because they strike the pool surface at a small angle of incidence

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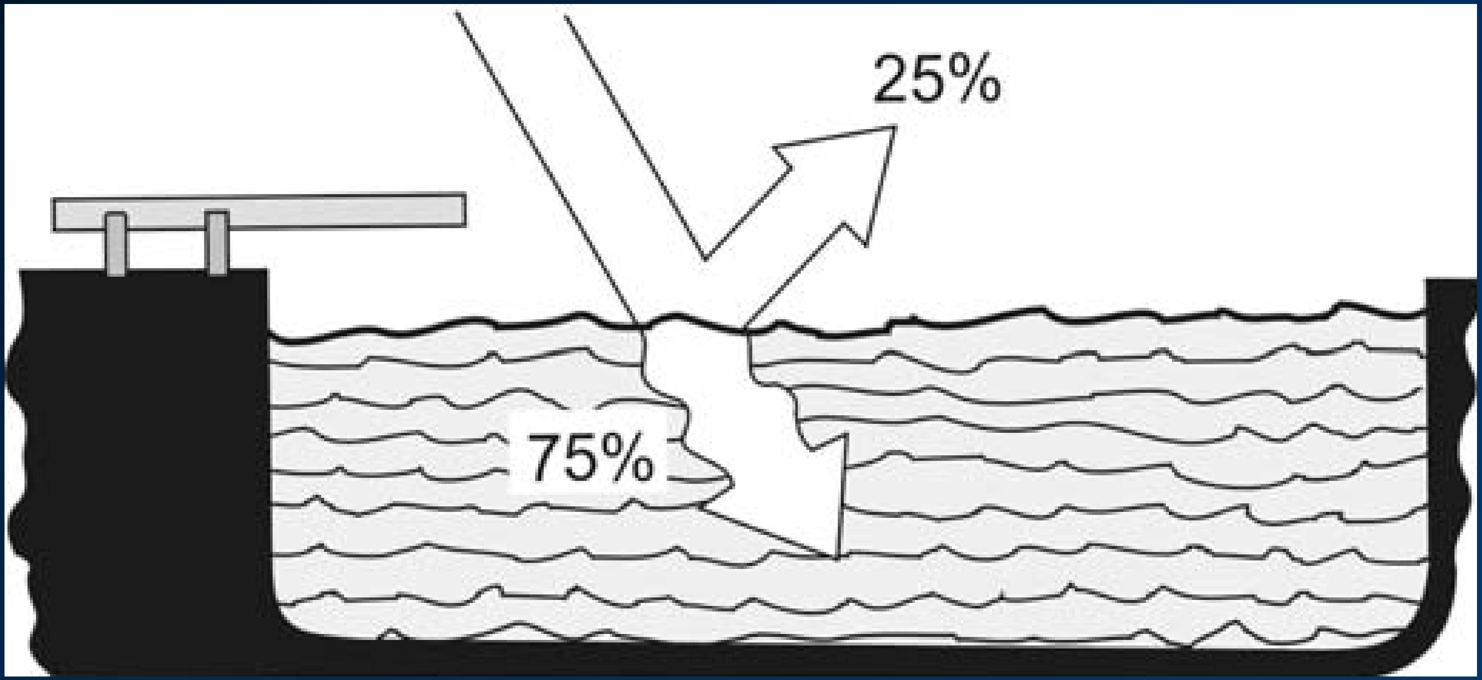

The swimming pool as a solar collector

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Screen Enclosures

- Screen enclosures reduce the amount of solar energy that strikes the pool surface
- When the sun shines perpendicularly to the screen material, only about 15 percent of the energy is obstructed since the screen area is 85 percent open air space
- When the sun strikes the material at an angle, much less of the radiation gets through, and the amount available to warm the pool is reduced
- Experiments conducted at FSEC place this reduction as high as 30-40 percent on a clear day
  - More auxiliary energy will be required to maintain comfortable swimming temperatures if the pool has a screen enclosure.

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Windspeed Reduction

- Reducing wind velocity at the water surface reduces convective and evaporative losses
- Solid fences or tall hedges located close to the pool perimeter are effective windbreaks
- Buildings, trees and mounds also protect the pool from the cooling effect of prevailing winter winds
- Locate the pool to take maximum advantage of these obstructions, being careful they do not shade the water surface from the sun
- Windbreaks are particularly desirable near the ocean or adjacent to lakes, where the average wind speed is higher than in more sheltered locations

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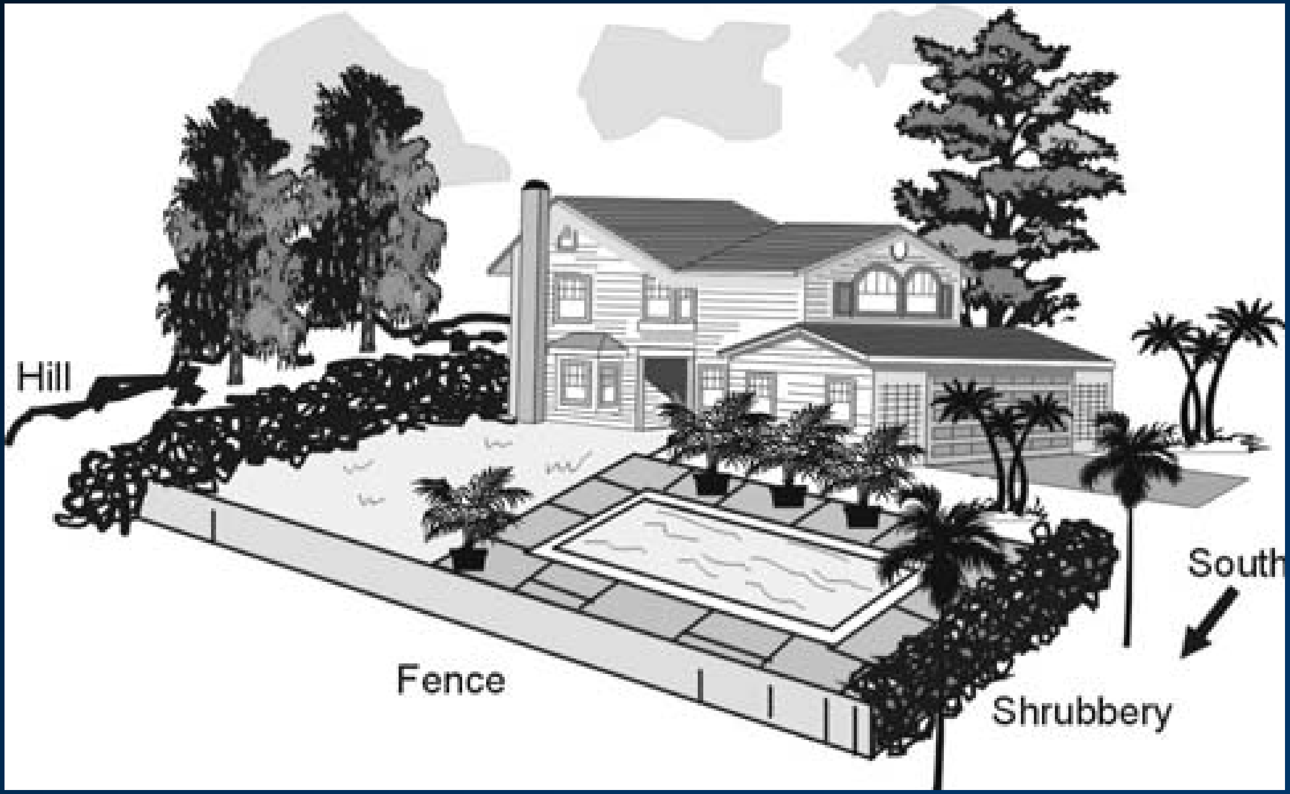
Windspeed Reduction



A well-protected pool

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Pool Covers

- Pool covers are effective in reducing heat losses
- There are two basic types of pool covers on the market today: opaque and transparent
- By reducing evaporation they reduce the quantity of chemicals needed, and they help to keep dirt and leaves out of the pool
- Pool covers also reduce pool maintenance costs

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Transparent Pool Covers

- Transparent covers will not only reduce evaporative losses
  - Will turn the pool into a passive solar collector
  - Sunlight passes through the cover material and is absorbed by the pool water
- Evaporation accounts for about 70 percent of pool heat loss
  - Beneficial effect of pool covers can be dramatic

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Transparent Pool Covers

- Figure below shows the approximate number of additional days annually that an unshaded, sunscreened pool, well protected from the wind, can be maintained above 80°F through the use of transparent covers.

- For example, in Gainesville, which is in the north central zone, a pool cover used for 14 hours each day extends the swimming season by approximately two months.
  - The 14-hour period is assumed to include the coolest part of the day.
  - Values presented must be used cautiously because the figures are based on historical weather data and a future month or even year may deviate substantially from the average.

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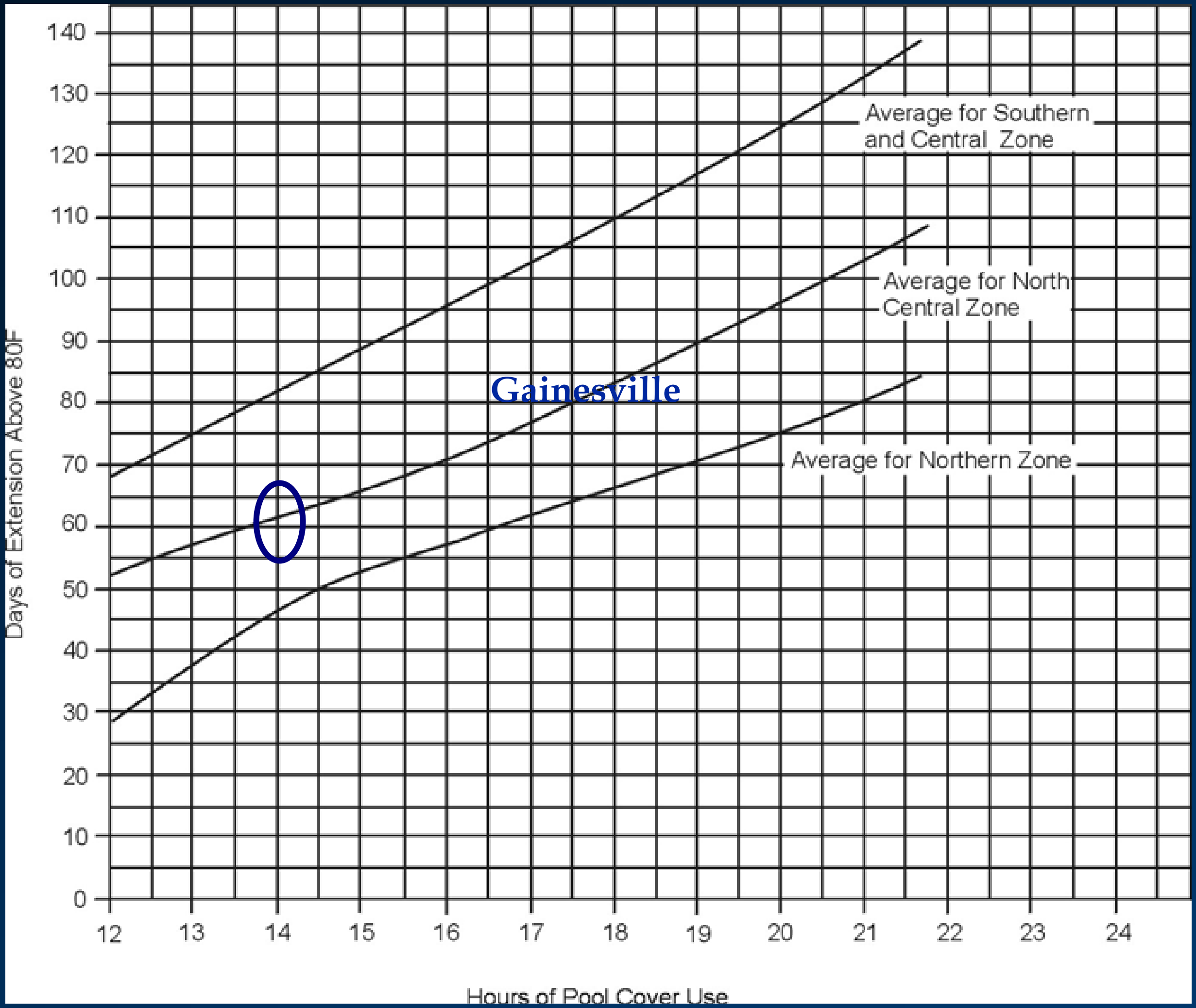
Transparent Pool Covers



Effect of pool covers: Extends season

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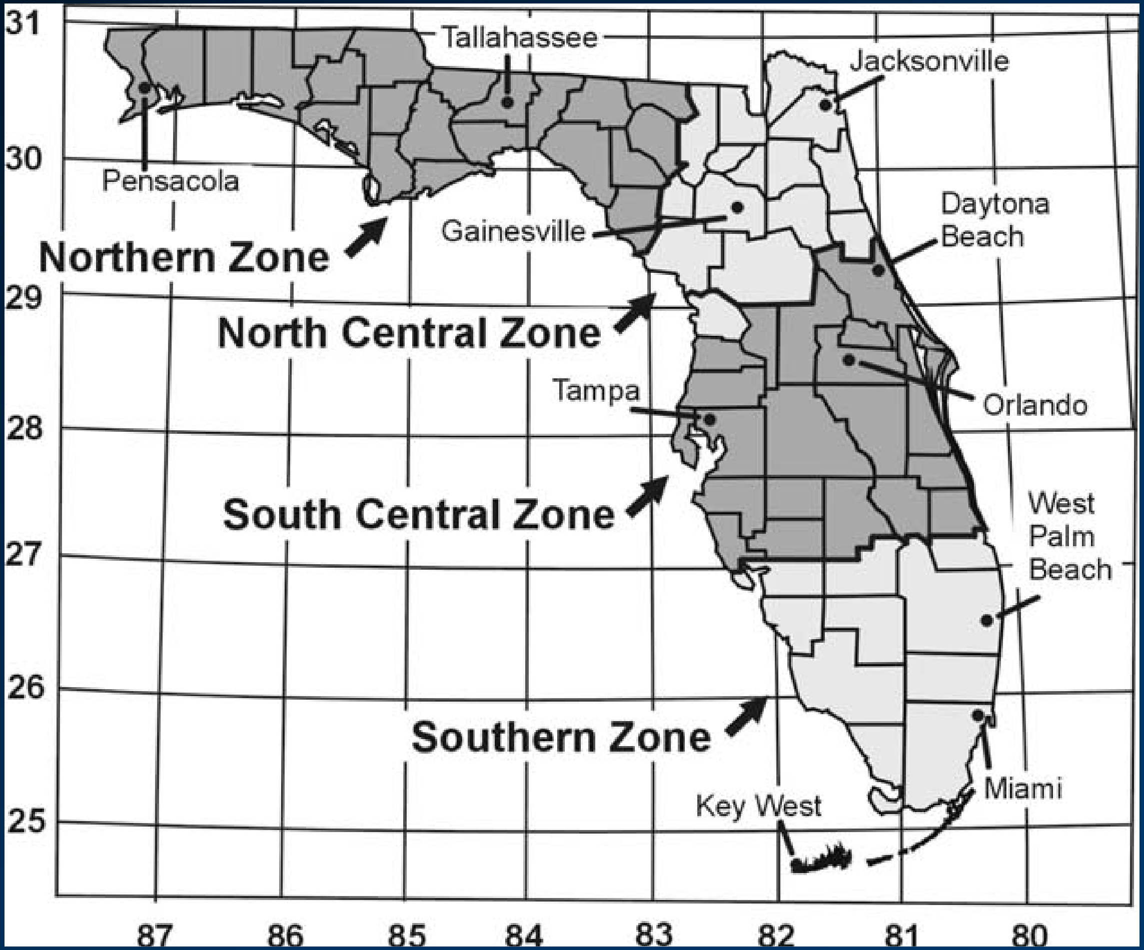
Transparent Pool Covers



Climatic zones of Florida

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Transparent Pool Covers

- Transparent pool covers are made from a variety of materials
  - polyethylene-vinyl copolymers, polyethylene and polyvinylchloride (PVC)

- Attention to a few details will extend the life of transparent pool covers.
  - They should not be left folded or rolled up on a hot deck or patio. The sunlight will overheat the inner layers and may even burst the air pockets in bubbled covers
  - When removing or installing a pool cover, avoid dragging it over the pool deck or any rough surface or sharp obstruction
  - Although it is recommended that a single, continuous pool cover be used whenever possible, the use of sectioned covers can ease handling in the case of larger pools

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Liquid Films

- Some companies that supply pool chemicals offer a liquid evaporation retarder, which may be dropped in minute quantities onto the pool surface
- Materials like cetyl alcohol spread to form a layer only a few molecules thick on a water surface
- They can reduce evaporation by nearly 60 percent
- Are fairly expensive and must be re-dosed frequently (usually at the close of the daily swimming period)
- The chemical films do not reduce convective or radiation losses, but they do allow solar gains

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Opaque Covers

- Opaque covers are useful for pools that must remain uncovered during daylight hours
- Most commercial pools fall into this category
- The following types of opaque covers are the most common:
  - Woven, plastic safety covers; skinned, flexible foam covers; and rigid or semi-rigid closed cell foam blocks or blankets
  - The woven safety covers will reduce evaporation losses (if they float and are waterproof) though not as well as a continuous film type cover.
  - Skinned foam covers vary in thickness from less than 1/8 inch to more than 1/2 inch.

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Opaque Covers

- In common insulating terms, their effectiveness in reducing heat losses ranges from R-1 to R-4
- If they fit snugly to the edges of the pool, they will virtually eliminate evaporation losses during the periods when they are in place
- Foam block covers such as expanded polystyrene have insulating values between R-4 and R-12, depending on their thickness.
  - If properly fitted and placed on the pool surface, they, too, will nearly eliminate evaporation losses during the hours they are used.
  - Their effectiveness in reducing convective and radiative losses increases directly with their R-value.

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Low-Temperature Collectors

- Types of low-temperature collectors include
  - black flat-plates
  - black flexible mats
  - black pipes

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Flat-Plate Collectors

- Flat-plate collectors feature large-diameter headers at each end and numerous small fluid passageways through the plate portion

- Header’s primary function
  - to distribute the flow of pool water evenly to the small passageways in the plate

- The header is large enough to serve as the distribution piping
  - reduces material and installation labor costs

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Flat-Plate Collectors

- Fluid passageways
  - Collect energy from the entire expanse of the surface
  - Are small and are spaced close together across the plate (if it is made of plastic)
  - Most of the collector surface is wetted on its back side.

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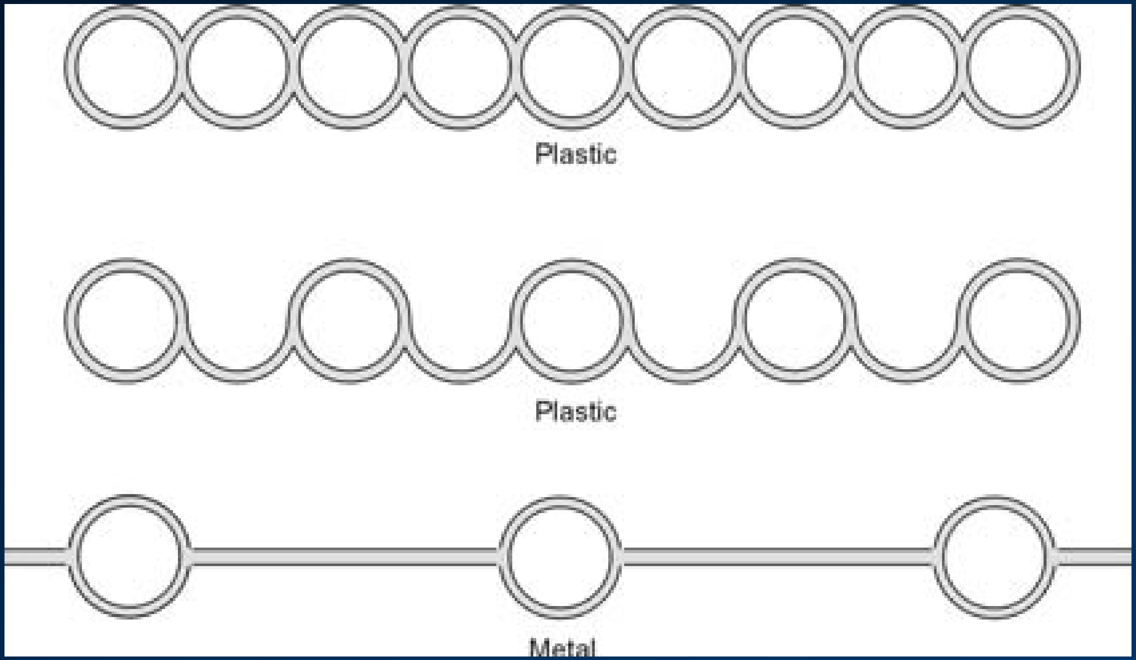
Flat-Plate Collectors



Representative cross sections of plastic collectors. EPDM flexible mat and plastic collectors have the same general cross section

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Flat-Plate Collectors

- High water flow rates also tend to keep collector-to-air-temperature differences low
- Total amount of energy delivered to the pool (the most important variable) is the product of the amount of water flowing through the collector multiplied by the water's temperature rise
- Five hundred gallons of water raised 1°F contains as much energy as 50 gallons of water raised 10°F
  - but the collector operating at 10°F above pool temperature will operate less efficiently
- High flow rates increase collector efficiency

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Flat-Plate Collectors

- Many manufacturers frequently recommend a flow rate as high as one gallon per minute for each 10 square feet of collector area
- such high flow rates are not needed to keep the temperature rise in the collectors below 10°F for best efficiency
- Higher flow rates result in high-pressure drops across the collector array and requires an increase in the horsepower of the circulating pump
- Flow rates are usually limited to about one gallon per minute for each 10 square feet of collector area

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Flat-Plate Collectors

- Plastic used must with-stand years of exposure to sunlight
- Ultraviolet portion of sunlight can break chemical bonds in most plastics and will eventually destroy the material
- Manufacturers use several proprietary combinations of additives or stabilizers and UV inhibitors in the chemical mix of the collector material
- Accurate estimation of plastic durability is difficult
- Most manufacturers currently offer a five-year or longer limited warranty. Some plastic collectors are expected to last 25 years

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Flat-Plate Collectors

- Plastics are available in numerous formulations and types
- Relatively immune to attack from common chemicals
- Polypropylene, acrylonitrile-butadiene-styrene (ABS), polyethylene, polybutylene, polyvinylchloride (PVC) and ethylene-propylene with diene monomer (EPDM)
- Used to make pool collectors for more than 20 years

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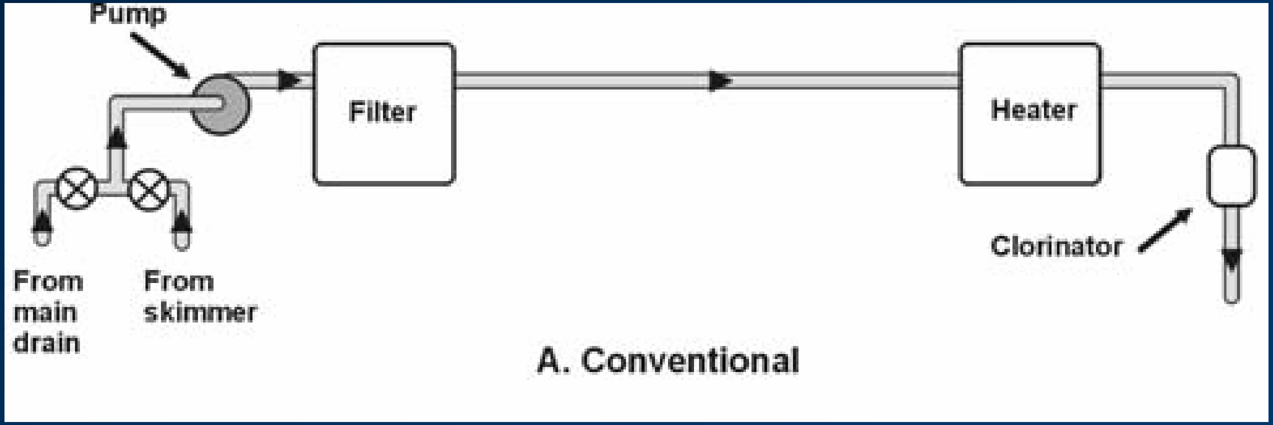
Flat-Plate Collectors

- Flat-plate collector designs utilizing metals are slightly different from plastic configurations
- Metal is a better heat conductor, so relatively long fins can separate the tubes without causing excessive operating temperatures on portions of the collector surface
- Metal collectors are generally not used for pool collectors in Florida because they are subject to corrosion from pool chemicals

Solar Pool Heating Systems

Flow Control Devices

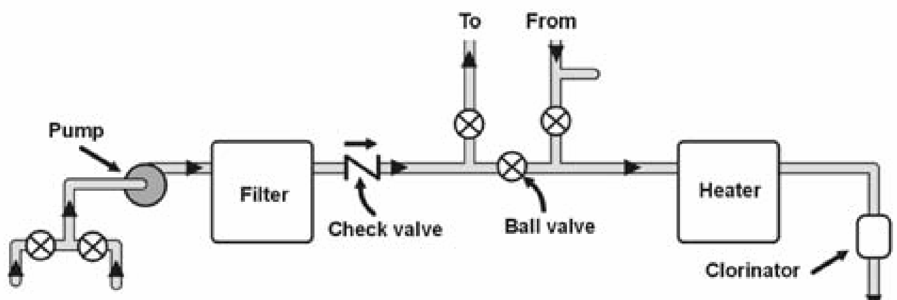
- Solar pool heaters are generally connected to existing pool plumbing systems
- Pump draws the water from the skimmer and main drain, forces it through the filter and returns it to the pool through the conventional heater
- Lint, hair and leaf catching strainers are usually installed ahead of the pump



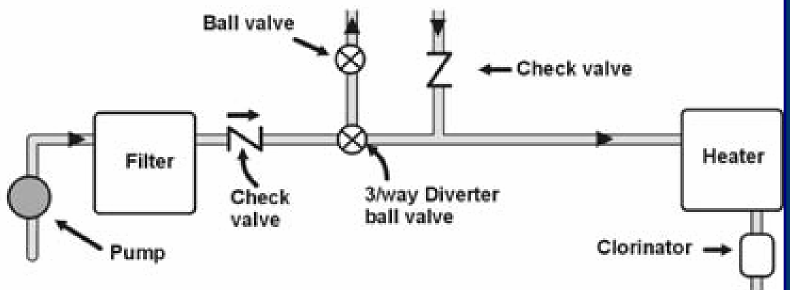
Solar Pool Heating Systems

Flow Control Devices

- Solar systems designed to operate with small pressure losses can be added
  - Spring-loaded check valve is installed
    - Prevents collector water from backwashing through the filter and flushing trash into the pool from the strainer when the pump is shut down
  - Manually operated or automatic valve is placed in the main line between Ts that feed the collector bank and return the solar heated water



C. Low Pressure Drop Solar System

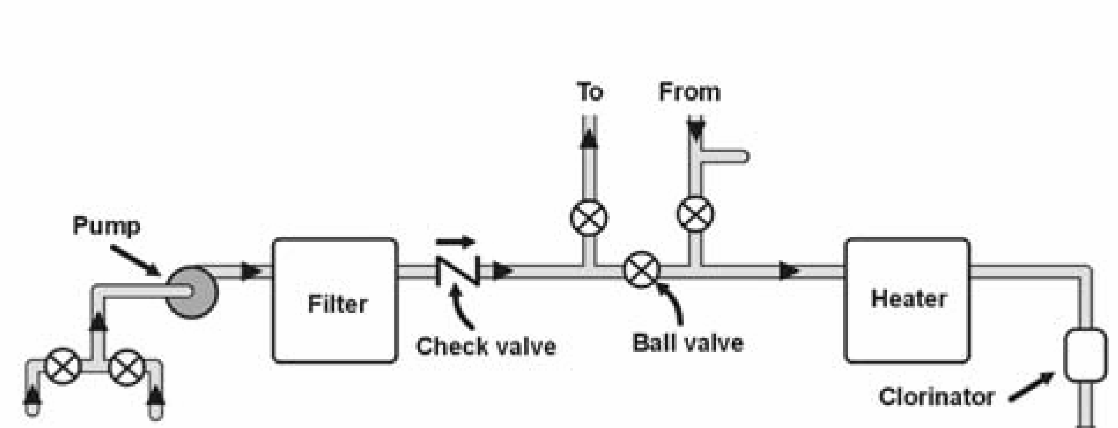


B. 3/Way Diverter

Solar Pool Heating Systems

Flow Control Devices

- Ball valves may be placed in the feed and return lines for isolating the solar system from the pool filtration system when the filter is being backwashed or when adjustments are being made to the solar system
- The valve in the main line is closed somewhat to restrict or fully interrupt the flow and force water up through the collectors
- Valves on the lines to and from the solar system should be fully open

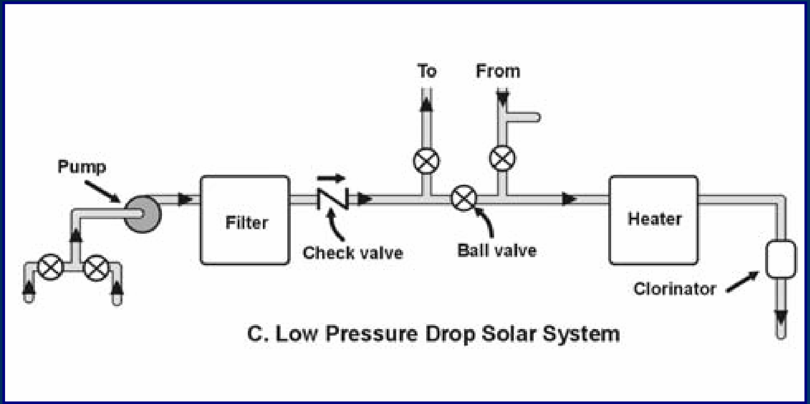


C. Low Pressure Drop Solar System

Solar Pool Heating Systems

Flow Control Devices

- Closing the valve in the main line may increase flow through the collectors
  - May seem logical to reduce the flow rate through the solar array to make the return water warmer
  - However, it is not logical – the collectors will be forced to operate at higher temperatures
  - Their efficiencies will drop, and less solar energy will be delivered to the pool
- Temperature rise through the collectors should be kept low, less than 10°F on warm, sunny days



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Flow Control Devices

- Forcing water through the solar system uses some of the pump's power, thus reducing the flow rate through the pool filtration system
- As the main line valve is closed, pressure on a gauge mounted on the filter or discharge side of the pump will rise slightly
- If the valve is closed entirely, all of the flow is diverted through the solar array and the collection efficiency increases
- If the pressure at the filter does not rise unduly, the solar system should be operated in this way

Solar Pool Heating Systems

Flow Control Devices

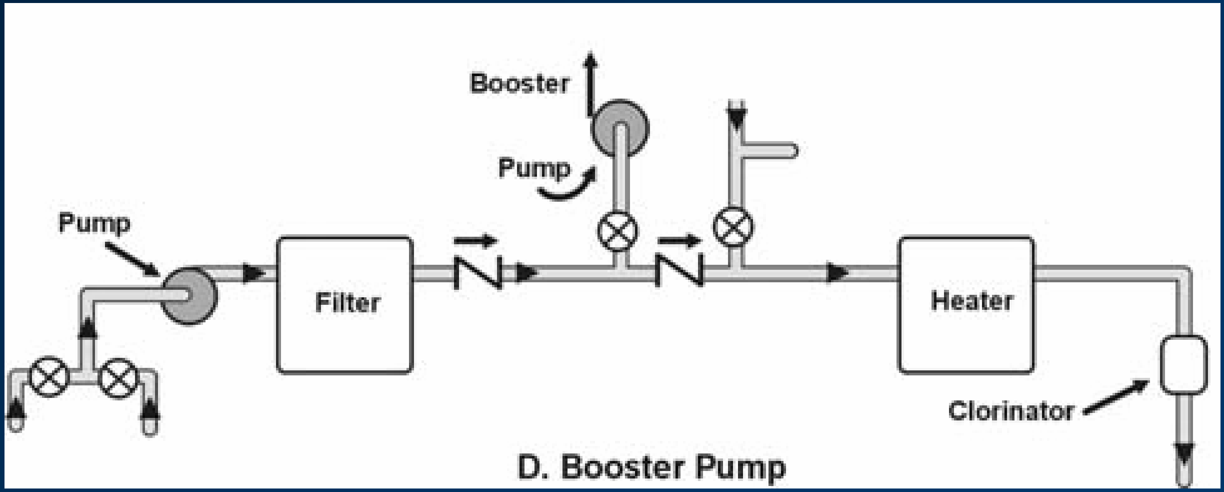
- The more the pressure rises, the slower the flow through the filtration system
- This will increase the length of time required for the entire pool's contents to be filtered
- It may be necessary to allow some of the flow to bypass the collectors
- An inexpensive plastic flow meter can be used on the main line connection to monitor flow rates through the filtration system
- Check with local building officials to determine minimum filtration flow rates or pool turnover times required in your area

Solar Pool Heating Systems

Flow Control Devices

- When the existing pool pump lacks enough power to circulate sufficient flow through the solar system and the filtration system, a booster pump may be required

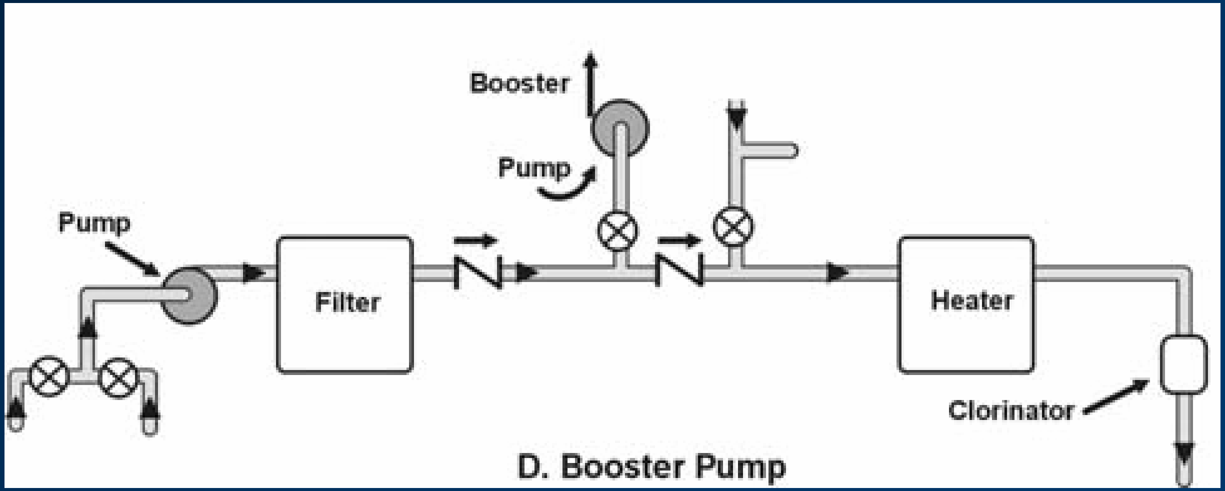
- Common pool-circulating pumps with or without the strainer basket are suitable for this application



Solar Pool Heating Systems

Flow Control Devices

- Booster pump should be placed in the line feeding the solar collectors, not in the main circulation line
- In this position it will operate (consuming electricity) only when circulation through the solar collectors is wanted
- the booster pump may be operated by the same time clock as that for the filter pump
  - more often it will have a separate control



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Flow Control Devices

- If both pumps operate from the same timer, it should be set so the pumps come on during daylight hours
- If the booster pump is separately controlled, the filter pump may run for a longer portion of the day, and the booster pump should turn on during appropriate periods but only when the filter pump is operating

Solar Pool Heating Systems

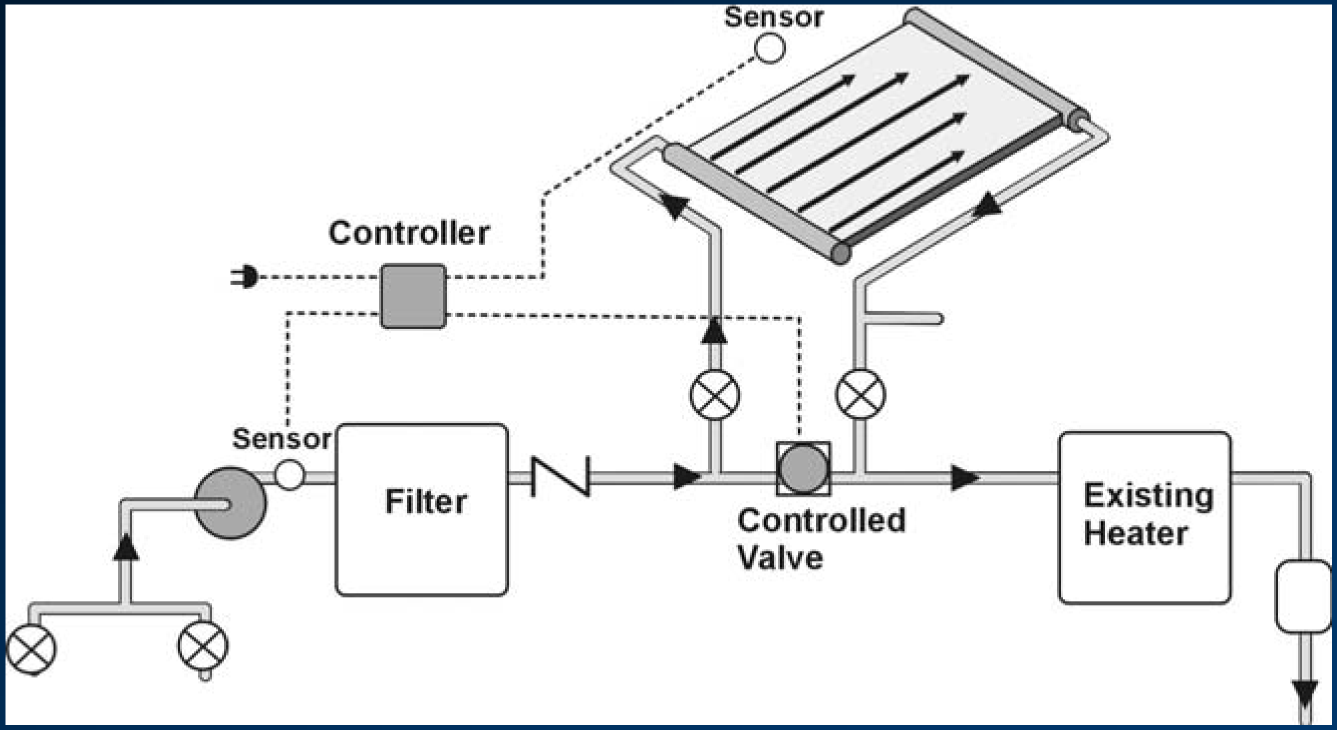
Flow Control Devices

- Manual flow control or control with time clocks is simple and inexpensive but has drawbacks
- Circulating pump may be running when there is insufficient solar energy
- Collectors may lose energy rather than gain
- Automatic flow controls overcome this difficulty

Solar Pool Heating Systems

Flow Control Devices

- The most common plumbing schematic for systems using these automatic devices



Automatic control plumbing schematic

Solar Pool Heating Systems

Flow Control Devices

- Accurate differential temperature control is difficult to achieve because of the small temperature rise that takes place in solar pool heaters
- A sensor, tapped into the piping at a convenient place ahead of the collector return line, measures the pool water temperature.
- Another sensor is housed in a plastic block and placed near the solar collectors, so its temperature parallels that of the collector (or it may be attached to the collector outlet).

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Flow Control Devices

- When the pool water temperature exceeds the collector temperature, the control valve remains in the open position and the flow bypasses the collector loop
- When the collector temperature exceeds the pool water temperature, the valve is closed, forcing the flow through the collectors
- In practice it has proven equally effective to control the flow through the collectors with a single solar sensor, which turns on the solar pump and/or activates the diverting valve above a fixed solar intensity level

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Flow Control Devices

- A differential controller automatically adjusts to changing conditions, monitoring variations in collector temperature caused by clouds, other weather factors and the approach of evening
- When collector temperature drops, the control de-energizes the valve and flow bypasses the collector
- Maximum pool temperature limits can be programmed into some controls

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Flow Control Devices

- Control valves may be actuated hydraulically or electrically
- One of the earliest valves used was a hydraulically operated pinch valve consisting of a cylinder with an expandable bladder inside
- A high-pressure line connected to the discharge side of the pump is used to expand the bladder, pinching off the flow and diverting it through the solar system
- A low-pressure line connected to the suction side of the pump deflates the bladder and allows the flow to pass unimpeded
- An automatic controller accomplishes switching between the high- and low-pressure lines

Pinch Valve

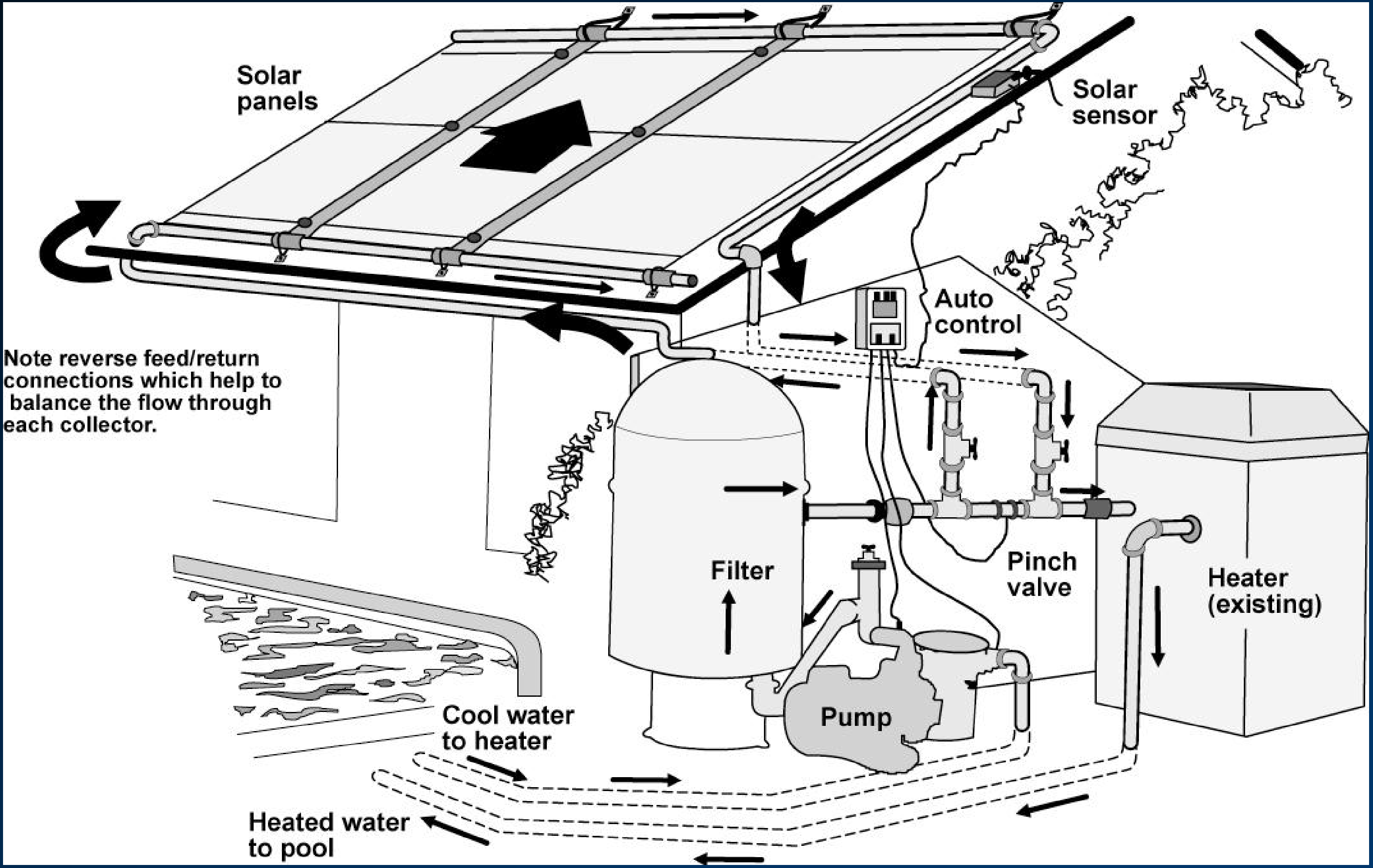

16°
18°
20°
22°
24°
26°
28°
30°
32°
34°
36°
TEMP. OBTAINED
HEATING
COOLING
DANGER FROST
OFF
ON
AUTOMATIC
FAFCO SC 3.1

Solar Pool Heating Systems

Flow Control Devices

- Electrically operated valves are also used
- A differential controller may be used to operate a solenoid that, in turn, activates the main valve in much the same way the pinch valve is activated
- Be sure the valve you select is specifically designed and constructed for use on pool systems
- Examples of automatic control schematics follow

Solar Pool Heating Systems



Automatic control

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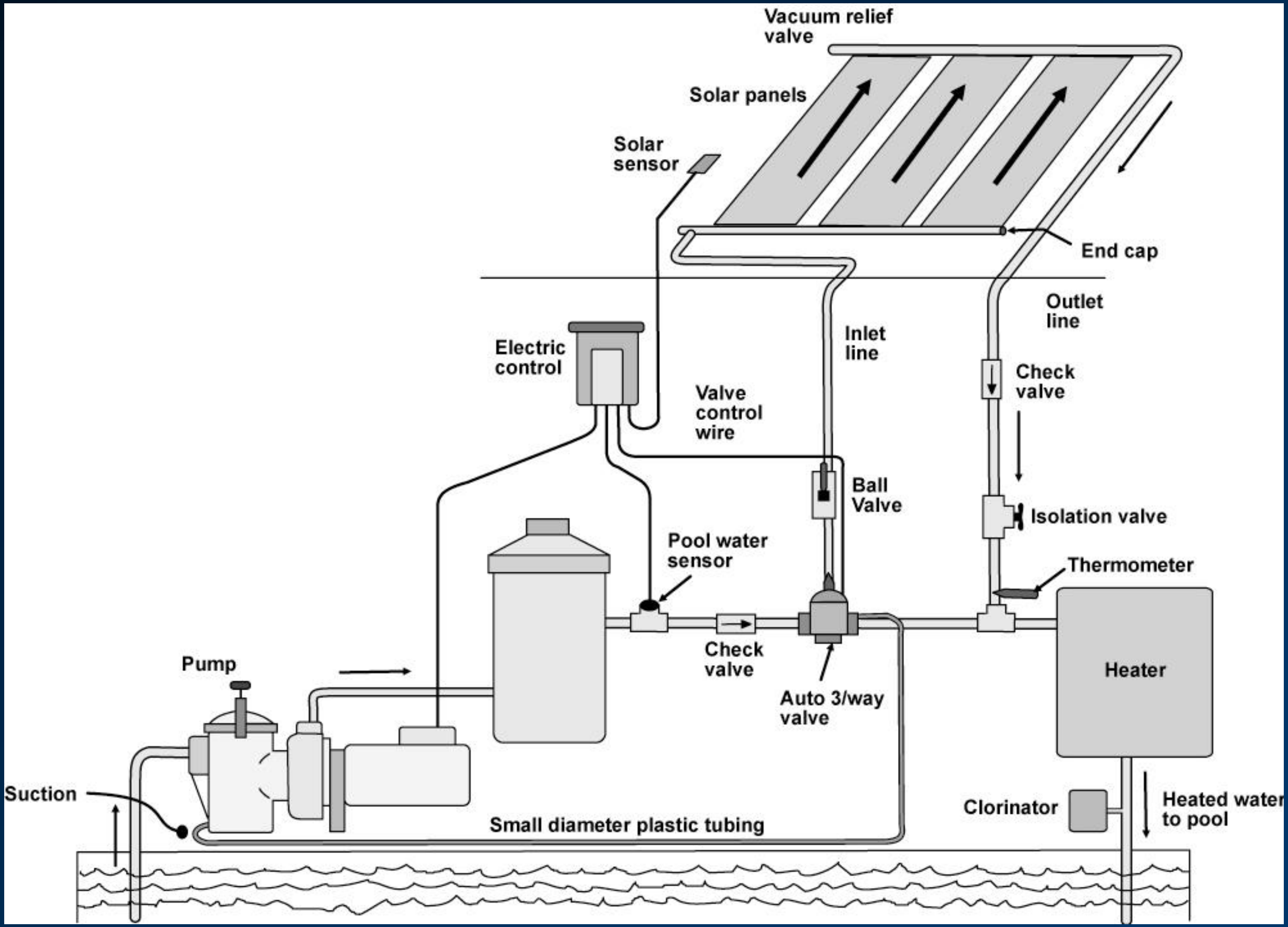

Automatic control

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Flow Control Devices

- The most common method to divert the flow of water to the solar collectors from the pool is to use a 3-way valve on the solar supply line
- Similar to the in-line ball valve or isolation valve, the three-way diverter valve is commonly used in the swimming pool and spa industries
- Some of the 3-way manual valves are made to be used for solar pool heating
- The 3-way valve has a motorized diverter that attaches to the top of the valve to convert the manual valve into an automatic or motorized valve

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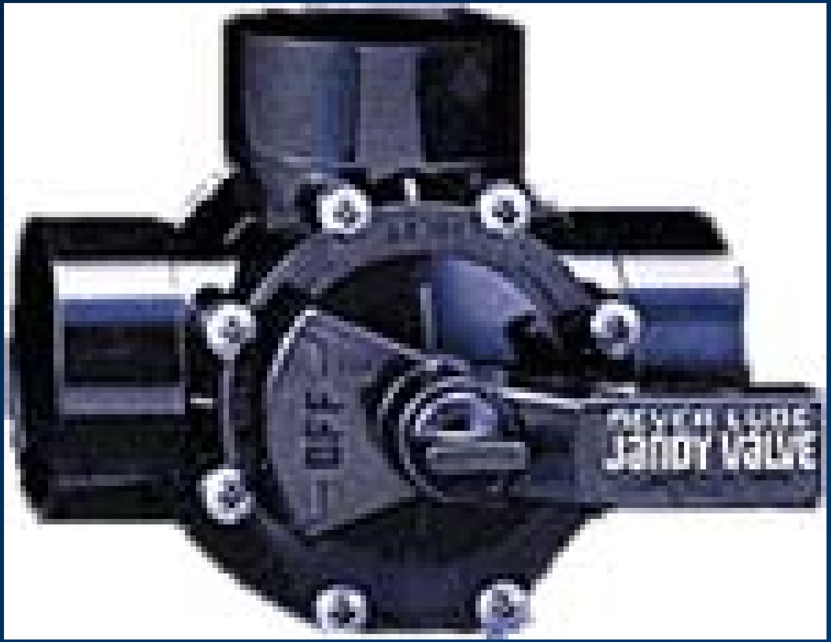
Flow Control Devices

- Other 3-way diverter valves are manufactured with the motor assembly on the valve
- In this case, a differential controller sends low voltage power to the diverter actuator (or motor) and rotates the valve sending the water from the filter to the solar collectors
- A check valve after the 3-way valve allows the solar collectors to drain into the pool when the pump is not operating
- This may provide freeze protection if the system tilt and piping was installed to allow continuous drainage.

3-Way Valve

With motor



Manual only

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Corrosion Problems

- Improper pool chemistry can cause accelerated corrosion
- The pool water pH should normally be maintained between 7.4 and 7.8
- PH is a measure of the acidic and basic character of a solution. A pH of 1-7 is on the acidic side
- The lower the number the more acid it is
- A pH of 7-14 represents increasing alkalinity
- Low pH (less than 7.2) may be caused by improper use of pool additives
- Under acid conditions (low pH), chloride and sulfate ions in the pool combine with water to form acids capable of breaking down protective films
- Low pH also accelerates the corrosion of most metals

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Corrosion Problems

- Excessive concentrations of copper ions in pool water may lead to the formation of colored precipitates on the pool wall if the pH is allowed to drop
- Several copper compounds have been identified as causing this problem
  - since many common algaecides are based on copper compounds, the concentration of free copper ions in pool water may relate to the use of these chemicals as well as the corrosion of copper piping materials
- Care should be exercised in maintaining proper pH levels whether copper or plastic piping is used in a solar pool heater

Solar Pool Heating Systems

Sizing Filter Pumps and Pipe Runs

- For simple installations, sizing the filters, pumps and pipe runs to circulate and keep the necessary pool water clean and heated may be successfully accomplished by following the instructions contained in the following sections
- For large or complex installations, more detailed manuals or a person knowledgeable with hydraulics should be consulted
- A basic knowledge of the characteristics of a swimming pool’s circulation system will be useful to installers in selecting the components appropriate for the solar heating of a specific pool

Solar Pool Heating Systems

Sizing Filtration and Circulation Systems

- Proper sizing of swimming pool filters, circulation pumps and pipe runs may be accomplished by using the information provided in this section in conjunction with data routinely provided by manufacturers of those components

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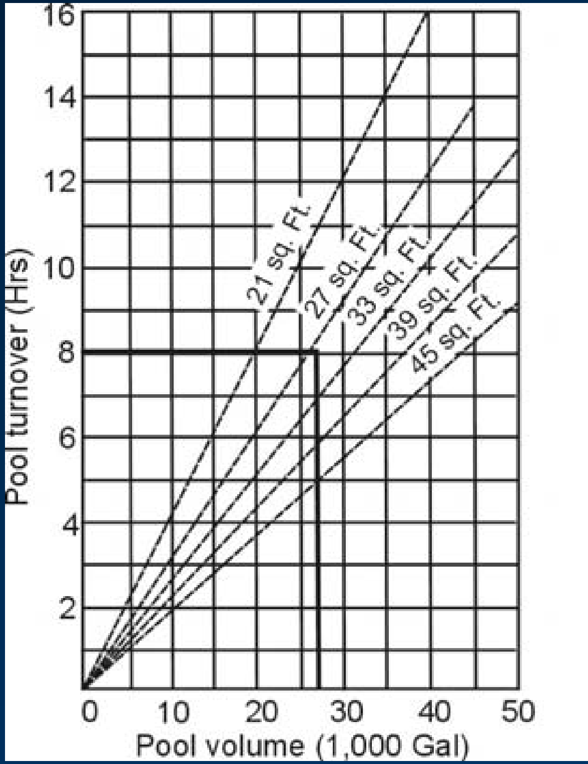
Filter Sizing Graphs

- Filter sizing is accomplished by using graphs provided by filter manufacturers.



Diatomaceous earth filter sizing graph for flow rate of 2 gpm/ft2

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Filter Sizing Graphs

- The following types of filters are those most often used to keep swimming pools clean
  - Sand
  - Gravel
  - Anthracite
- Sand, gravel or anthracite filters are sometimes operated at a flow rate as high as 20 gallons per minute (gpm)/ft2
  - some code jurisdictions limit the flow rate through these filters to three gpm/ft2

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Filter Sizing Graphs

- Diatomaceous earth (DE) filters usually operate well at about two gpm/ft2
- Both sand and DE filters may be cleaned by backwashing and discharging the dirty water into a sewer or other appropriate outlet
  - An air gap in the discharge line is often required to ensure against backflow contamination from the sewer
- Cartridge filters are usually operated at a flow rate of about one gpm/ft2 and may be reverse flushed and reused
  - When the cartridges become excessively dirty they are simply replaced.

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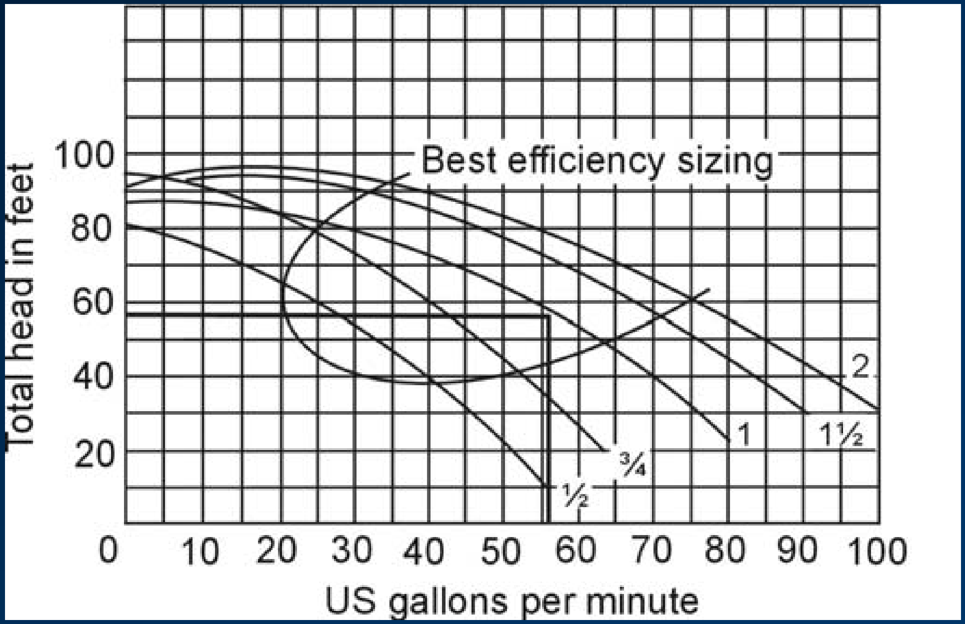
Filter Sizing Graphs

- In pool filtration systems, the need for cleaning is indicated by high readings on a pressure gauge, which is located between the filter and the pump
- Filter manufacturers specify the readings at which they recommend maintenance
- The pressure drop due to properly sized clean filters is usually about five psi
- The backwashing valve assembly on DE and sand filters may add another five psi

Solar Pool Heating Systems

Pump Sizing Graphs

- To size the pumps establish a flow rate in gpm and add up all the pressure drops (head) that occur when water flows through the system at a certain rate
- Pressure drop and flow rate plot for typical pool pump

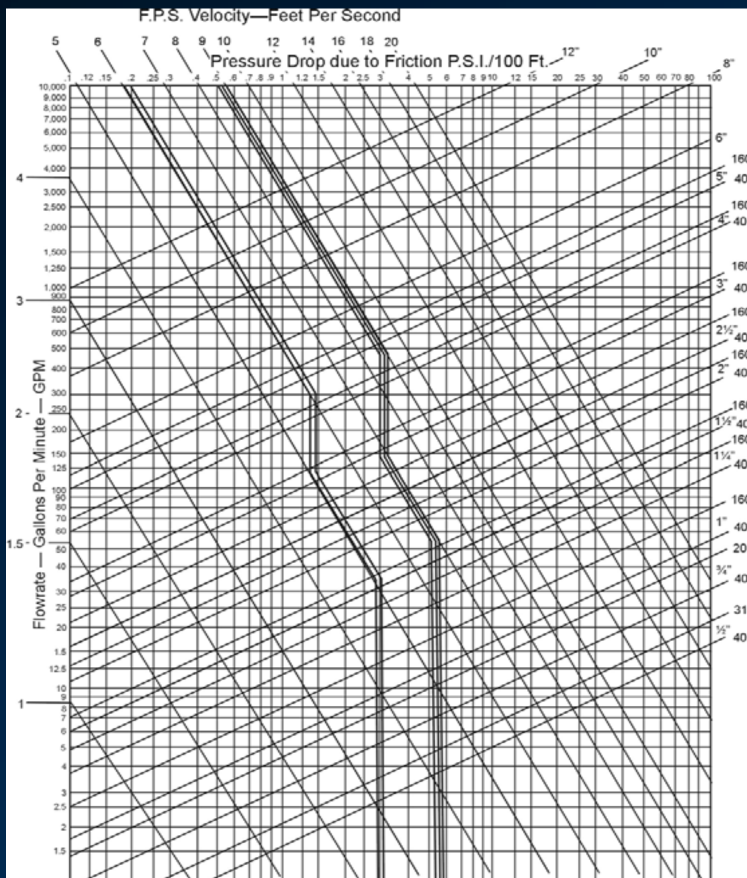


Pump performance

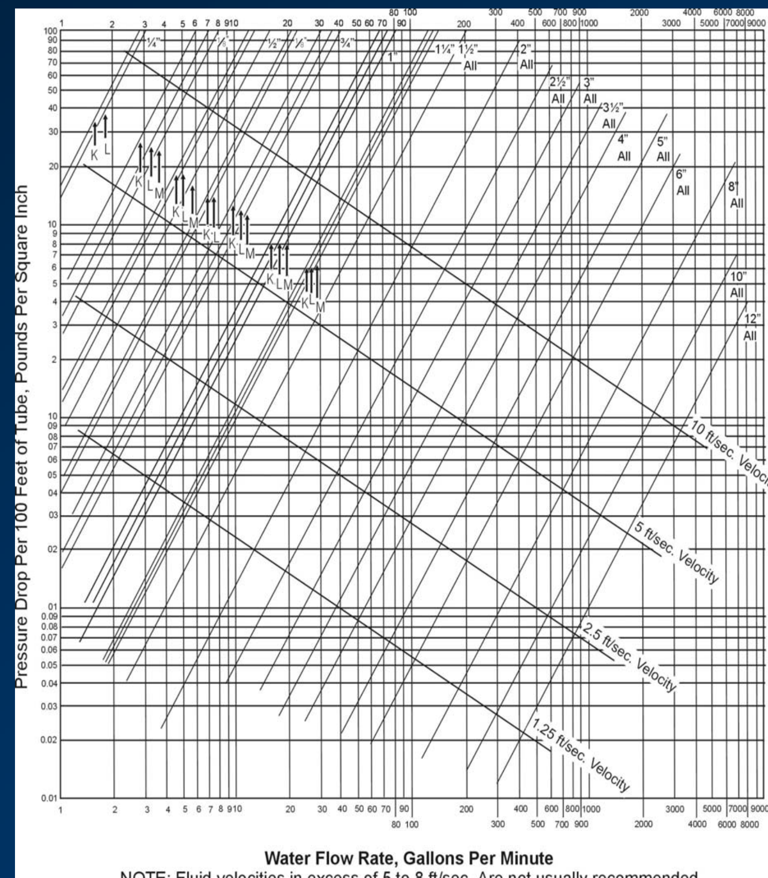
Solar Pool Heating Systems

Sizing Connecting Piping

- Connecting piping may be sized using pipe flow charts



Pressure drop plastic pipe



Pressure loss and velocity relationships for water flowing in copper pipe

Solar Pool Heating Systems

Sizing Connecting Piping – Example

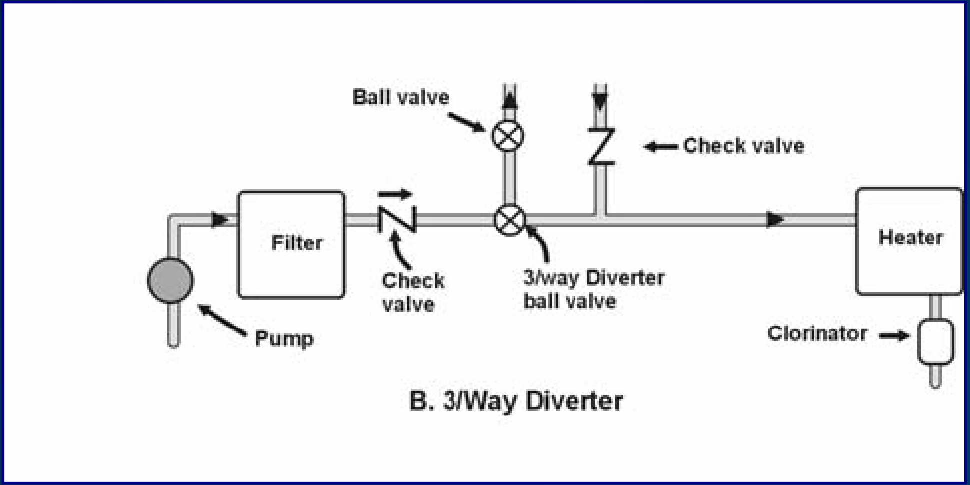
- Examples help clarify sizing procedures
- 20’ x 40’ swimming pool
- Average depth of 4.5’
- Circulate total pool volume through filter in 8 hours
- DE filter

- Wants to know?
  - What size filter and pump will be required
    - With no heater
    - With a gas heater
    - With a solar and gas heater for back-up
    - With solar without back-up
  - What size connecting pipe should be installed

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Pump will be located with center of impeller 3’ above surface of pool
- 100’ of pipe will be required unless solar collectors are used
  - If solar used, 200’ of pipe required
- High point of solar array will be 12’ above pump
- Collectors connected as indicated below



Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 1
  - Determine the pool volume
  - Pool volume (gal) = 20’ x 40’ x 4.5’ x 7.48/ft^2 = <u>26,900 gal</u>
- Step 2
  - Determine DE filter cross section area if 2 gpm/ft^2 of filter area is an acceptable flow rate through the filter
  - And the pool volume must turn over every 8 hours

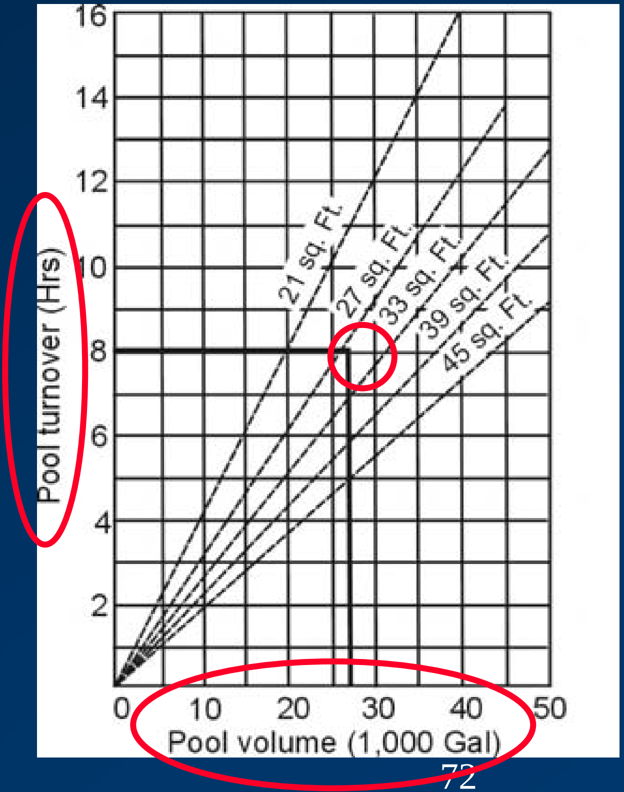
Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 2 (Cont)
  - DE filter graph indicates a cross sectional area between 27/ft^2 and 33/ft^2 will be required
  - Use filter that provides 33/ft^2 of filter area
    - Will allow a slightly less than 8 hr turnover

Pool turnover – 8 hrs

Pool volume – 26,900 gal



Diatomaceous earth filter sizing graph for flow rate of 2 gpm/ft2

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 3
  - Determine the flow rate through filtration system
  - Since entire volume must turn over once each 8 hours
    - Flow rate = 26,900/8 = 3360 gallons per hour (gpm)
    - <u>Flow rate = 3,360/60 = 56 gpm</u>

Solar Pool Heating Systems

Sizing Connecting Piping – Example

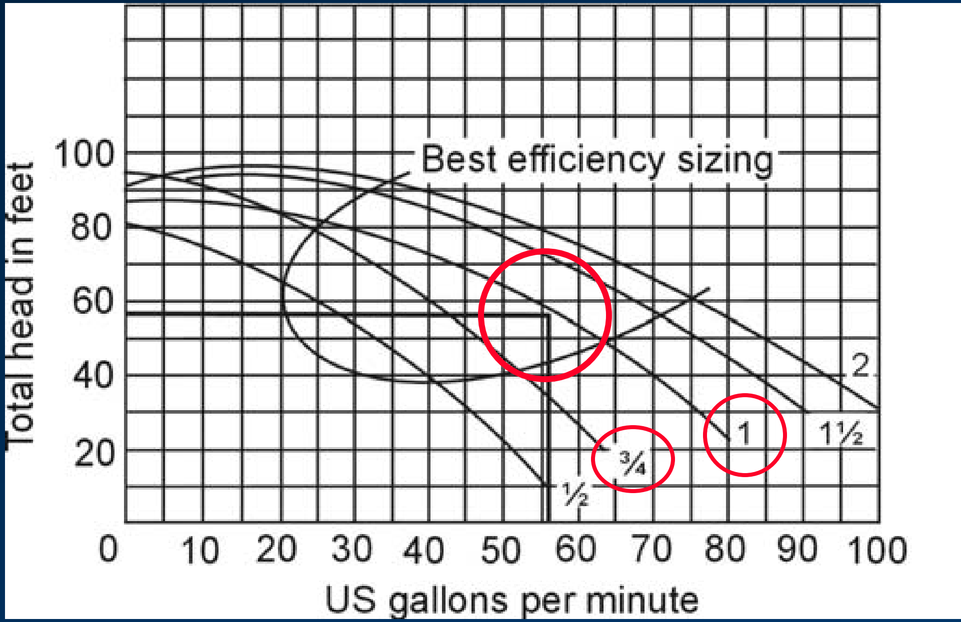
- Step 4
  - If no heater is included in the system, determine the total pressure, which the pump will be required to overcome at a flow rate of 54 gpm

Cause of Pressure Drop	Source of Information	Pressure Drop	
		Lbs/In^2 (Psi)	**Ft of Water (Psi x 2.31)**
100 ft 1-1/2" schedule 40 plastic pipe	Figure 14 (Pressure drop – plastic pipe)	8	18.5
Fitting	About 1/2 of pipe drop	4	9.2
Valves	Manufacturer’s specs.	5	11.6
Filter	Manufacturer’s specs.	5	11.6
Lift head			3
Total			**54**

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 4 (Cont)
- Pump performance graph indicates a 1 hp pump will circulate 56 gpm against a 57’ head
- A ¾ hp pump will circulate only 45 gpm against a 51’ head
- The 1 hp pump is the safest choice



1 hp pump: performance graph

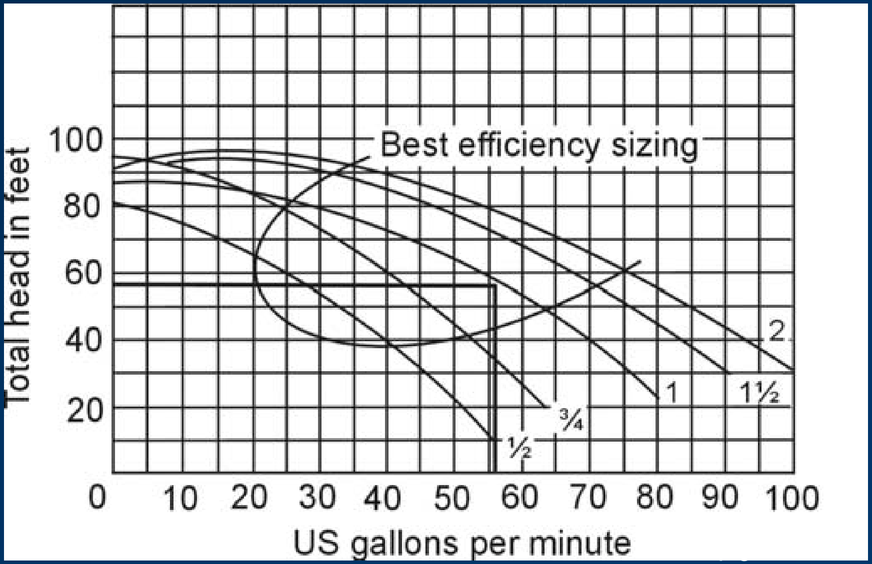
Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 5
  - Determine the size of the pump required if a gas-fired pool heater is added
    - Causes an additional pressure drop of 5 psi
    - Pump curve indicates 1 hp pump will pump ~ 50 gpm against 65' of water. Close enough but turnover is 9 hrs.

Cause of Pressure Drop	Pressure Drop Psi	Pressure Drop Ft of Water
100 ft –1 1/2" schedule 40 plastic pipe	8	18.5
Fittings	4	9.2
Valves	5	11.6
Filter	5	11.6
Pool heater	5	11.6
Lift head		3
Total		**65**

Pressure drop determination



1 hp pump: performance graph

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 6
  - Determine the size pump that will be required if a solar system and gas fired back-up heater are used
  - A pressure drop of 2 psi is expected across the solar collectors
  - System contains an extra 100’ of pipe and a vacuum breaker located 12’ above the pump

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 6 (Cont)

Cause of Pressure Drop	Pressure Drop	
	Psi	Ft of Water
100 ft of 1 1/2" pipe	8	18.5
Fittings for 1 1/2" pipe	4	9.2
100 ft of 2" pipe	3	6.9
Fittings for 2" pipe	1+	2.3+
Valves	5	11.6
Filter	5	11.6
Solar panels	2	4.6
Gas heater	5	11.6
Static head (3' + 12')		15
Total		**92**

Using 1 ½″ and 2″ pipe

Cause of Pressure Drop	Pressure Drop	
	Psi	Ft of Water
200 ft of 2" pipe	6	13.9
Fittings for 2" pipe	3	6.9
Valves	5	11.6
Filter	5	11.6
Solar panels	2	4.6
Gas heater	5	11.6
Static head (3' + 12')		15
Total		**75**

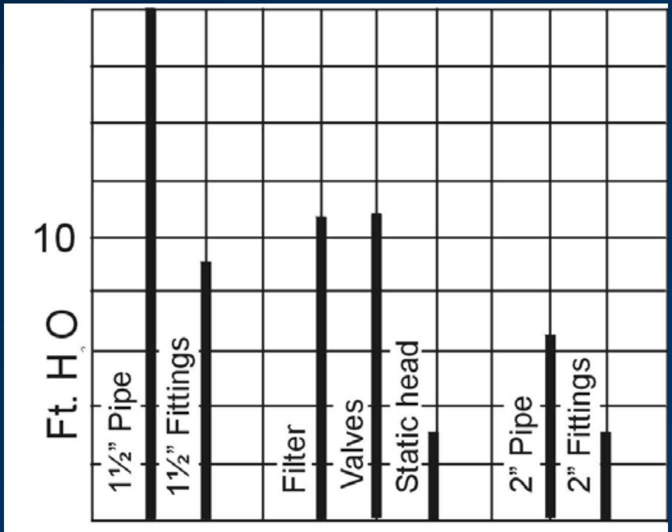
Using only 2″ pipe

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Step 6 (Cont)
- Relative pressure plot shows if 100’ of 1 ½” pipe and 100’ of 2” pipe are used
  - A 2 hp pump will move only 35 gpm against 92’ head
  - Increases turnover time to ~ 13 hours
  - Thus, a 2 ½ hp pump will be required

Relative pressure

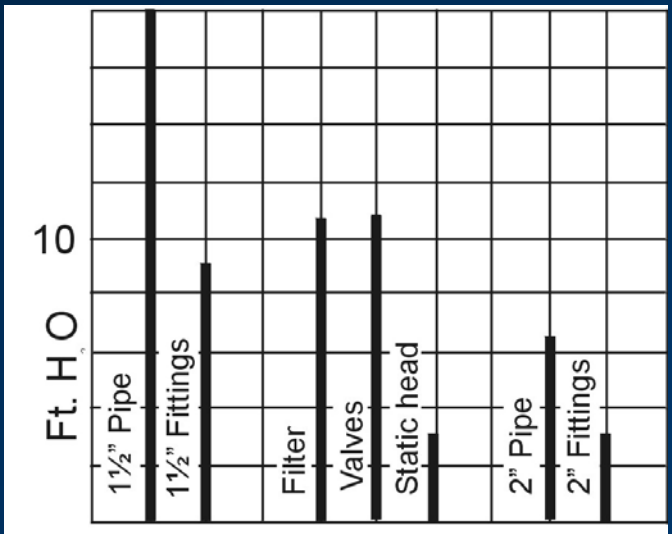


Solar Pool Heating Systems

Sizing Connecting Piping – Example

Step 6 (Cont)

- If 200’ of 2” pipe is used, a 1 ½ hp pump will move 52 gpm against the 75’ head
- 52 gpm will turn the pool volume over in an acceptable period of time (8.6 hrs)



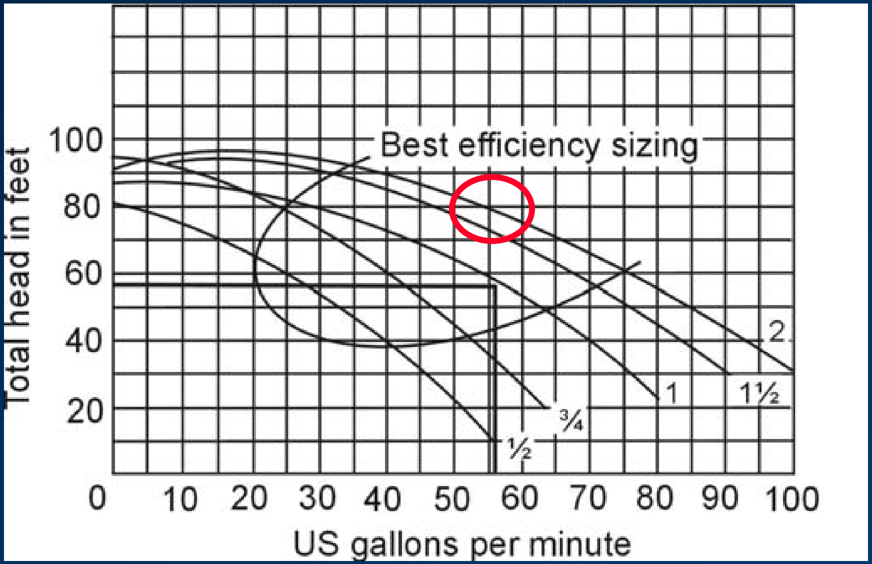
Relative pressure

Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Final Option – Solar Only
  - Elimination of gas heater reduces pressure drop from 92 to 80’ of water
    - If an additional 100’ of 1” pipe and 100’ of 2” pipe are used to make the connections
  - Pump graph indicates a 2 hp pump will pump 54 gpm against an 80’ head (turnover time is 8.3 hours)

1 hp pump: performance graph

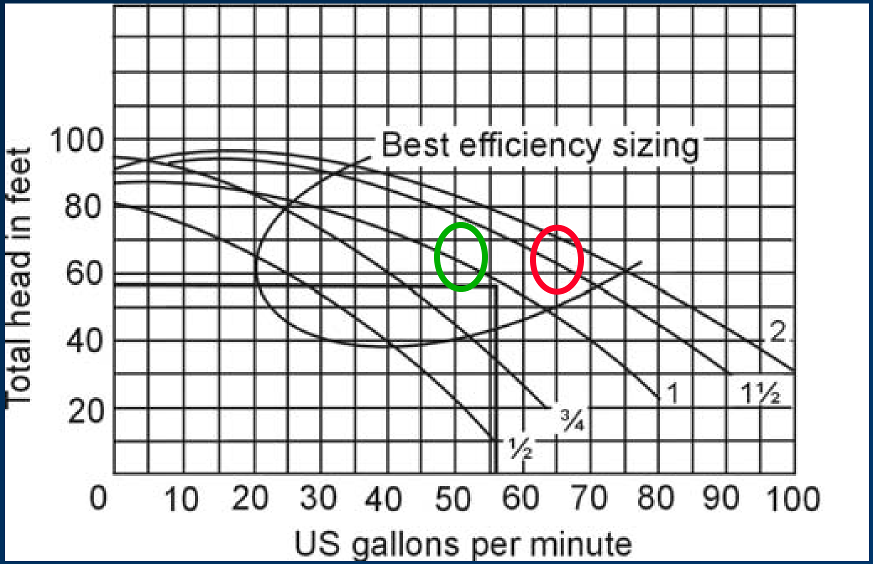


Solar Pool Heating Systems

Sizing Connecting Piping – Example

- Final Option – Solar Only
  - If 2” connecting pipe is used throughout, total pressure drop is reduced to about 63’ and a 1 hp pump will deliver 50 gpm against a 63’ head (turnover time is 9 hours)
  - A 1.5 hp pump will circulate about 65 gpm against a 63’ head (turnover time is 7 ½ hours)

1 hp pump: performance graph



Solar Pool Heating Systems

Sizing Connecting Piping

- Pool heating options and pipe and pump sizes which yield the various pool turnover time periods
- None of the options alter the turnover rate of the pool sufficiently to require resizing the DE filter

Components	Pipe Size	Pump Size Required	Turnover Time (In hours)
System with no heater	100 ft of 1 1/2" schedule 40 plastic	1 hp	8
	100 ft of 2" schedule 40 plastic	3/4 hp	8.6
System with gas or oil heater (5 psi pressure drop)	100 ft of 1 1/2"	1 hp	9
	100 ft of 2"	1 hp	7.2
System with gas and solar (15 ft static head)	100 ft of 1 1/2" plus 100 ft of 2"	2 1/2 hp	8
	200 ft 1 1/2"	2 pumps (1 hp+3/4 hp)	8
	200 ft 2"	1 hp	8.6
System with solar only (15 ft static head)	100 ft 1 1/2" plus 100 ft 2"	2 hp	8.3
	200 ft 2"	1 hp	9
		1 hp	7.5

Solar Pool Heating Systems

Pressure Drop Across the Valves and Fittings

- Designers use simple rules of thumb to determine pressure drops cause by resistance valves and filters
- Important to realize the actual pressure drop varies with both flow rate and mechanical characteristics of valves and fittings
- Use a reference table that indicates frictional losses expressed in equivalent lengths of pipe for commonly used fittings
  - Manufacturers provide this
- Sum of the equivalent length of all fittings on the circulation system may be added to the actual length of pipe in the system before pressure drop is read from the Pressure Drop graph for either plastic or copper piping

Solar Pool Heating Systems

Friction Loss Table

Type of fitting	Material (in ")	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	10	12
Standard tee with flow through branch	Steel	6	8	9	11	14	16	-	20	26	31	40	51	61
	Plastic	9	12	13	17	20	23	-	29	-	45	-	-	-
	Copper	6	8	9	11	14	16	18	20	26	31	40	-	-
90 degree long radius elbow, or run of standard tee	Steel	1.7	2.3	2.8	3.6	4.2	5.2	-	6.8	8.5	10	14	17	20
	Plastic	3	4	5	7	8	10	-	12	-	17	-	-	-
	Copper	1.7	2.3	2.8	3.6	4.2	5.2	6.1	6.8	8.5	10	14	-	-
Adapter slip/ solder fitting to thread insert coupling	Plastic	3	3	3	3	3	3	-	3	-	3	-	-	-
	Copper	1	1	1	1	1	1	1	1	1	1	1	-	-
	Plastic	3	3	3	3	3	3	-	3	-	3	-	-	-
Gate Valve (fully open)	-	.60	.80	.95	1.15	1.4	1.6	1.9	2.1	2.7	3.2	4.3	5.3	6.4
Swing Check Valve	-	7	9	11	13	16	20	23	26	33	39	52	67	77
Ordinary entrance	-	1.5	2.0	2.4	3.0	3.7	4.5	5.2	6.0	7.3	9.0	12	15	17

Solar Pool Heating Systems

Energy Conservation

- System should be properly sized
- Installers responsibilities do not end there
- This requires large enough pipe diameters
  - to keep their friction losses low
  - proper flow through the solar collectors to maximize heat collection yet minimize pressure drop
  - adequate collector sizing to minimize the number of hours the pump must operate each day
  - Pointless to oversize the solar-related components to an extent that reduces the time required for heat collection below that required for acceptable filtration

Solar Pool Heating Systems

Collector Installation

- Optimum collector slope for spring and fall operation is equal to the latitude of the site
- The best slope for winter is the latitude plus 15° and the collectors should face south if possible
- If roof space, which faces within 45° of south, is available, the collectors can be mounted directly on the roof
- Only a small penalty is paid for modest deviations from optimum slope or orientation
- Supports can be constructed to mount collectors at the ideal orientation, but except in new construction, the additional cost is generally prohibitive
- Occasionally it may be necessary to increase the collector area to compensate for less than optimum slopes or orientations

Solar Pool Heating Systems

Collector Installation

- Collectors should be securely fastened to withstand maximum expected wind loads
- Building code requirements for maximum wind velocities vary within the state of Florida from 100 to 146 miles per hour
- Wind loads at roof level may exceed 75 pounds per square foot. Check the local building regulations for wind load provisions

Solar Pool Heating Systems

Collector Installation – Procedures

- Always refer to the manufacturer's recommended installation procedures
- Lay out the collectors on the available roof area
  - avoid any area shaded by trees, parts of the building or other obstructions
- If large numbers of collectors are involved
  - may have to be divided into several banks with collectors in each bank plumbed in parallel
- Plumbing arrangements from bank to bank are discussed in the next section

Solar Pool Heating Systems

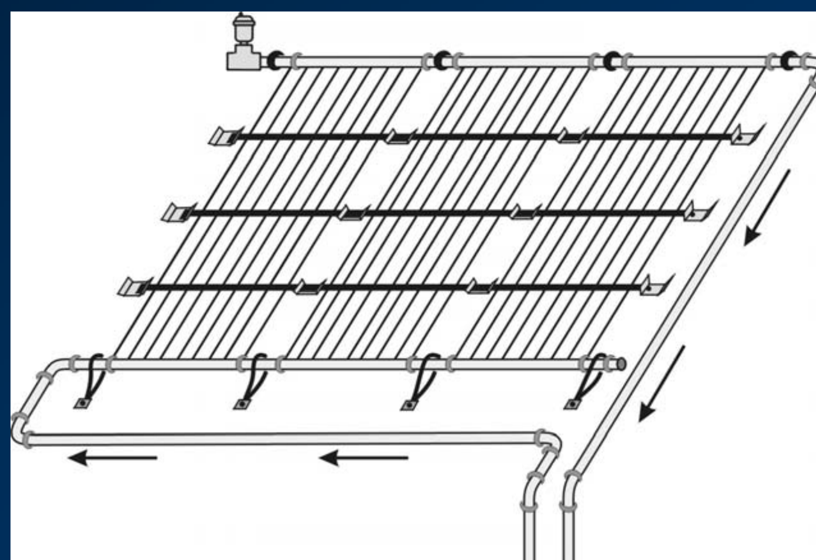
Collector Installation – Procedures

- Once the placement is established, the collectors should be connected
- Short, flexible couplings made of EPDM or butyl rubbers often are used
  - Usually are slipped over the ends of the headers and are clamped firmly with stainless steel clamps
  - Once fastened together, the collectors are cumbersome to move about
  - Be sure they're in their final positions before the connections are made

Solar Pool Heating Systems

Collector Installation – Procedures

- Collectors often are mounted directly on the roofs
- Collectors should be laid on the roof and fastened down at the header on both ends
- At least two, and preferably three, cross straps should span the panel to further secure it



Collector hold-down straps

Solar Pool Heating Systems

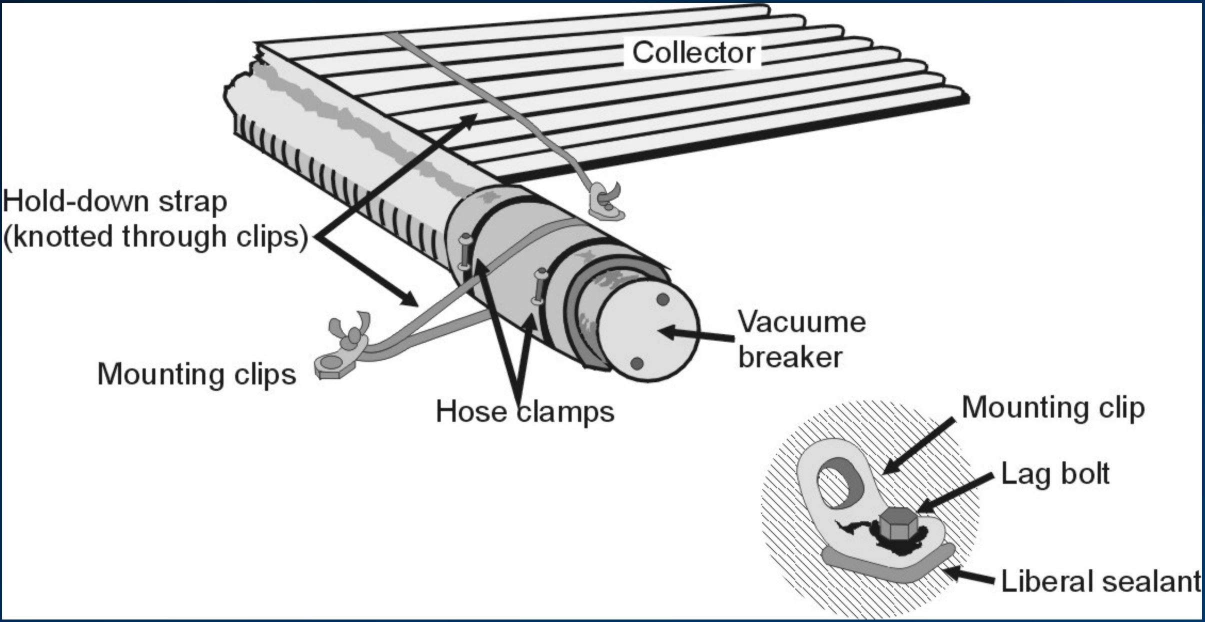
Collector Installation – Procedures

- One end of the panel can be fastened to the roof with a short strap or clamp around the header
- The other end should be fastened with an elastic material or spring to allow for expansion as the collector temperatures change
- – a 10-foot plastic collector may expand and contract as much as an inch in length
- Straps should be installed across the panel body – one at either end – within a foot of the headers, and one across the middle are recommended
- The straps should be made of material, such as nylon or plastic-coated metal, that will not scratch or abrade the collector since they will rub across its surface
- The bands should be snugged to clips fastened approximately an inch from the edge of the collector

Solar Pool Heating Systems

Collector Installation – Procedures

- Typical mounting clip, which may be made of rigid plastic or metal.



Typical collector mounting clip

Solar Pool Heating Systems

Collector Installation – Procedures - Shingles

- On asphalt shingle roofs, the clips may be fastened directly on top of the shingles – 1/4-inch lag bolts penetrate sheathing
- Lag screws should be screwed into as many roof rafters as possible (rather than just roof sheathing)
- A pilot hole should be drilled for the lag screw
- Sealant should be injected with a cartridge gun into the hole
- An excess of sealant should be used to form a seal between the mounting clip and the roofing material when the lag bolt is tightened
- Polysulfide and the newer polyurethane sealants adhere well to common building materials and appear to be very durable

Solar Pool Heating Systems

Collector Installation – Procedures – Built-Up

- Sealing mounting brackets on tar and gravel (built-up roofing)
- Requires careful cleaning around the bracket
- Scrape off the old gravel down to the tar, and clear off all dirt and residue
- If the tar surface is very dirty or irregular, soften it with a solvent such as mineral spirits
- After sealing the clip with polysulfide, pour roofing tar over the bracket base and cover with gravel
  - This necessary to prevent ultraviolet damage to the tar and premature roof failure

Solar Pool Heating Systems

Collector Installation – Procedures – Built-Up

- Mounting collectors on other roof types is more difficult
- On cedar shake roofs, mounting screws should pass through the shakes and fasten securely to the plywood or purlins beneath
- Don’t be stingy – use good quality sealant and enough of it to form a good, sealed penetration
- Don't tighten the fasteners tight enough to split the shake

Solar Pool Heating Systems

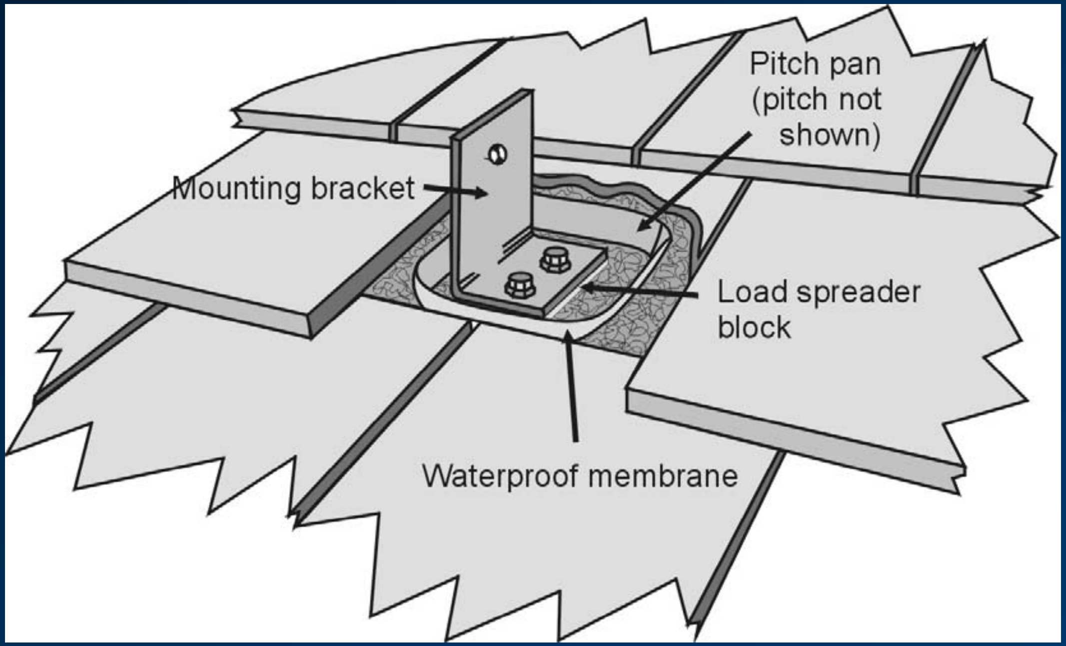
Collector Installation – Procedures - Tile

- Concrete tile roofs, especially common in south Florida, present special mounting difficulties
- The safest solution is to construct a rack to support the collectors above the tile surface
  - The rack should be constructed of a durable material, such as aluminum
  - It should be strong enough to withstand maximum anticipated wind loads
- Substrate and collectors may be fastened to the rack. The rack itself must be securely fastened to the roof trusses, not to the sheathing
- This practice should also be used when installing a reverse pitch rack on the backside of a roof

Solar Pool Heating Systems

Collector Installation – Procedures - Tile

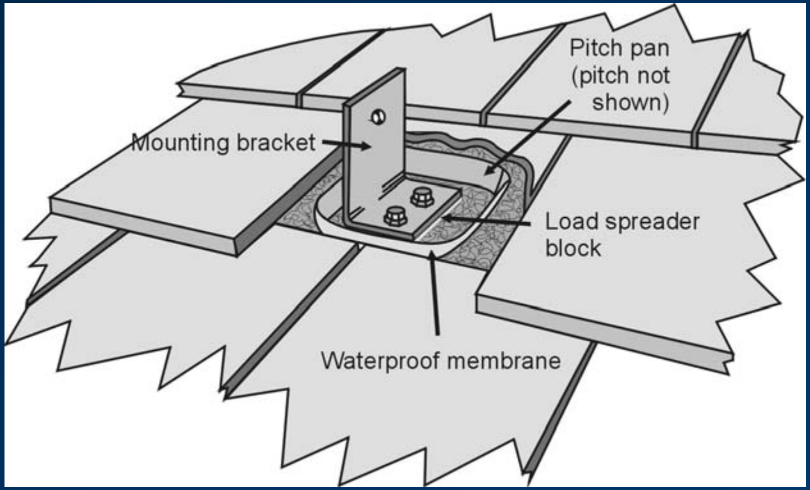
- Typical mounting bracket arrangement



Solar Pool Heating Systems

Collector Installation – Procedures - Tile

- To install the bracket, a tile must be removed or broken, exposing the waterproof membrane on the sheathing below
- This waterproof surface (commonly called slate), not the tiles, forms the moisture barrier and must be resealed where mounting bolts penetrate it



Solar Pool Heating Systems

Collector Installation – Procedures - Tile

- The mounting location should be free of dust and debris
- Roofing mastic should be applied to the bracket and slate to form a seal when the bracket is drawn down
  - (Pitch pans around the roof penetrations may be required in some areas.)
- A substitute for the broken tile may be made from cement mix (using adjacent tiles as a model) and tinted to match the roof
- Aluminum and copper materials should be protected from contact with the cement by a layer of tar to reduce corrosion

Solar Pool Heating Systems

Collector Installation – Procedures - Tile

- Fastening schemes have been proposed which rely upon sealing the roof penetration at the tile surface
- Since the waterproof membrane is not the tile itself but rather the slate membrane beneath, these methods are not effective and should be avoided

Solar Pool Heating Systems

Collector Installation – Procedures – Barrel Tile

- Spanish or barrel tile roofs present another tough collector mounting problem
- It is extremely difficult to walk on them without breaking some tiles
- Also difficult to make substitute tiles
- Proceed with caution

Solar Pool Heating Systems

Collector Installation – Procedures – Piping

- Solar swimming pool collectors are designed to operate with high flow rates
- The primary objective in piping solar systems is to provide
  - uniform, high-volume flow
  - at the lowest cost and the lowest pump power possible

Solar Pool Heating Systems

Collector Installation – Procedures – Piping to Collectors

- For low-temperature collectors, plastic pipe can be used in the plumbing from the pool pump to the solar collectors
- PVC and ABS pipe (Schedule 40) are the most commonly used materials for this particular application and have performed satisfactorily
- Neither material can withstand high temperatures
- Due to the moderate operating temperatures, pipe insulation is not required

Solar Pool Heating Systems

Collector Installation – Procedures – Piping to Collectors

- Local plumbing requirements should be adhered to when installing piping leading to and from the collectors
- Since large-diameter pipe is quite heavy when filled with water, sturdy supports will be required
- Pipe cuts should be deburred before assembly to reduce resistance to flow
- Leaks can be avoided by using the correct cement for the pipe involved and properly preparing joints
- Because plastic expands and contracts considerably with temperature changes, allowances should be made for change in length
- Your pipe supplier can provide you with specific data on the kind of pipe used for a particular job

Solar Pool Heating Systems

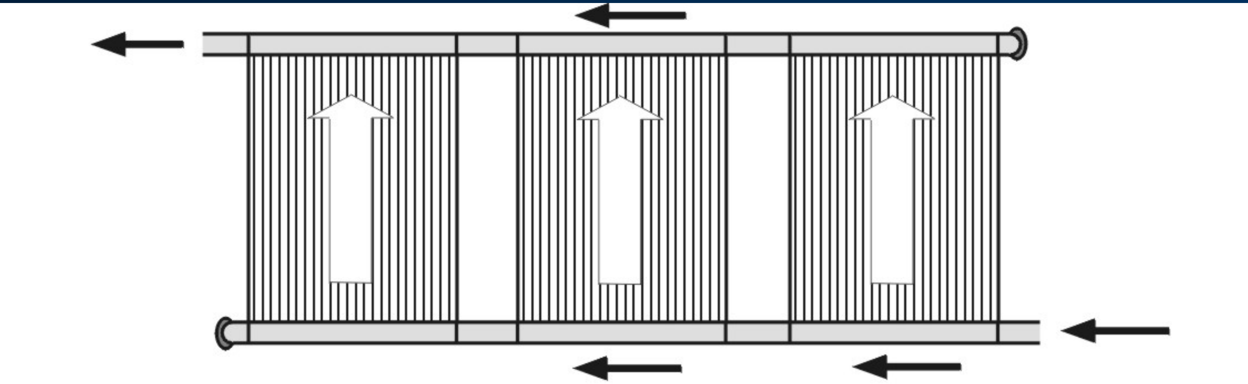
Collector Installation – Procedures
Piping between Collectors

- About the same amount of water should pass through each collector
- On large installations it is necessary to divide the solar collecting panels into groups and connect the groups with pipe
- This requires the piping layout be carefully designed and constructed
- Most situations encountered can be satisfied using principles discussed in this section
  - for extremely complicated cases it may be wise to consult a hydraulic flow specialist

Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- Pool heating collectors are almost always connected in parallel

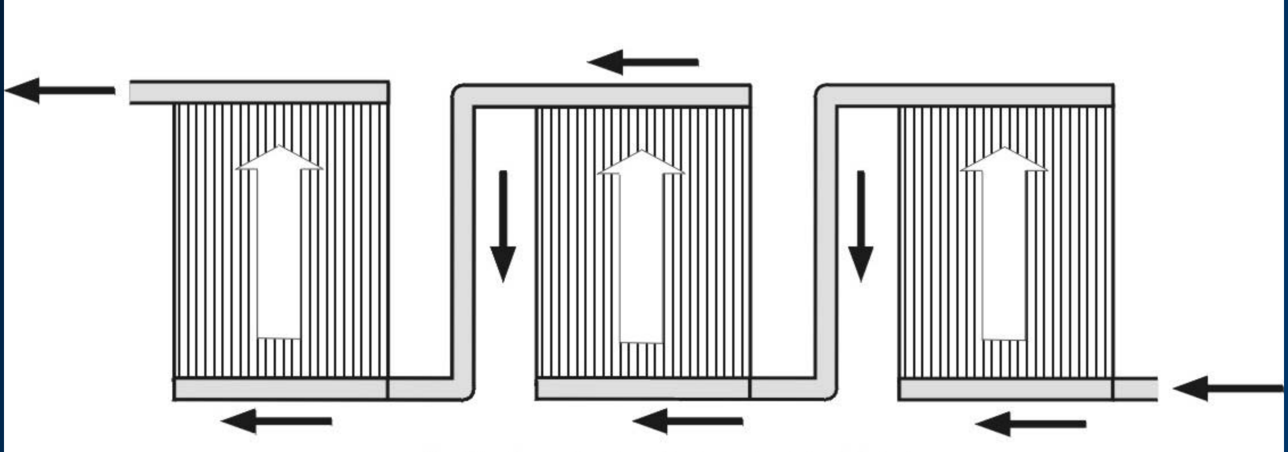


A. Parallel

Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- Series connections are less frequent

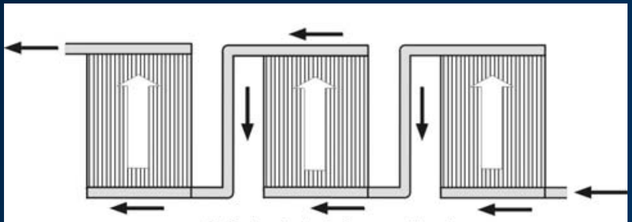


B. Series (note drainage problem)

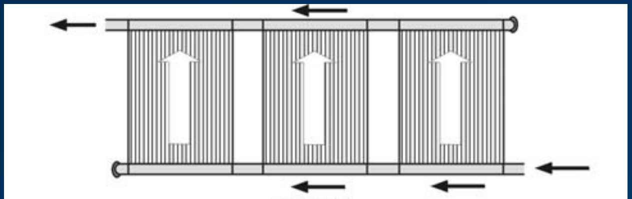
Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- In the series arrangement, water passes through one collector and then through the next
- Increases the pumping horsepower required to maintain adequate flow
- Causing the downstream collectors to operate at higher, less efficient temperatures


B. Series (note drainage problem)

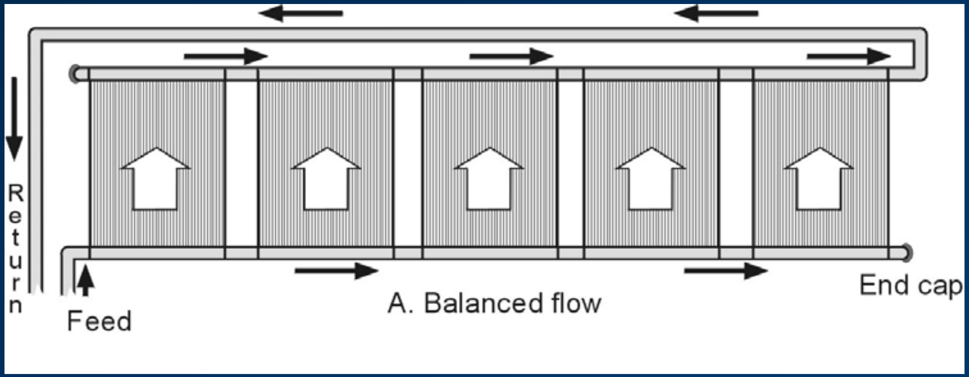
- Parallel connections, in which the water is returned directly back to the pool after passing through one collector, are the better choice because those difficulties are avoided


A. Parallel

Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

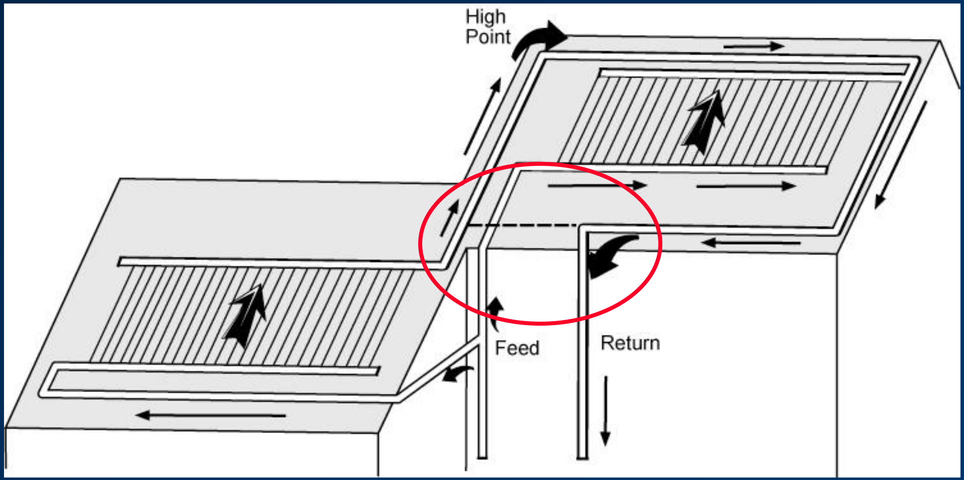
- The feed and return lines leading to each collector should be approximately the same length.
- Preferred arrangement – balanced flow
- Length of the water path is the same for all collectors
  - flow is evenly distributed
- Require extra pipe, but improved collector performance compensates for the additional cost



Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

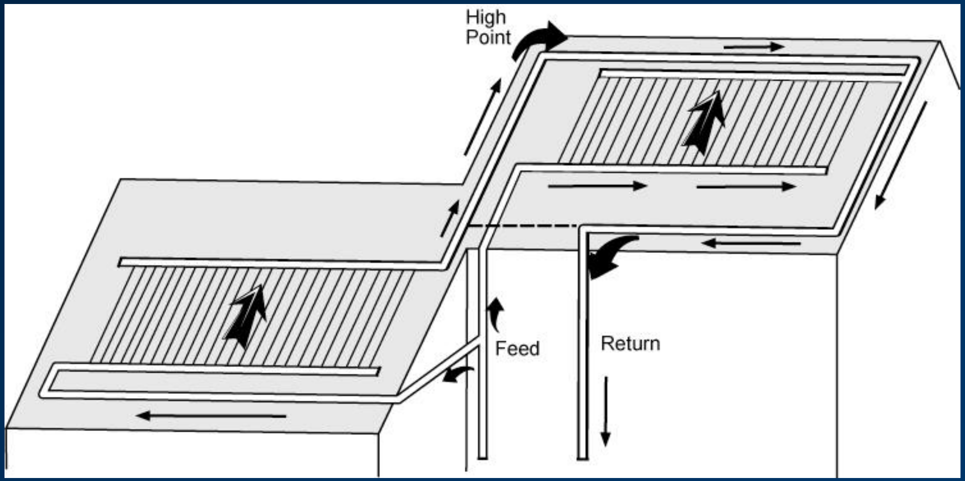
- Groups of collectors at different heights should be plumbed in such a way they all receive water from the lowest point in the system and return it from the highest point
- The dashed line indicates a tempting, but unsatisfactory, arrangement



Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- If the return lines do not come from a common height, flow through the panels will be uneven, causing a reduction in performance
- Even with this piping layout, a balancing valve may be required to reduce the flow rate in the lower collectors



Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- Balancing valves can be used to obtain uniform flow distribution in other difficult situations
  - when site requirements make it impractical to balance the flow with simple plumbing arrangements
- Balancing valves and, if economics permit, flow meters should be installed in the feed line to each group of collectors
- Starting with all valves completely open, gradually close the appropriate valve until the desired flow for each group is obtained
- An alternative to the use of flow meters is to measure the outlet temperature of the various collector groups and adjust the balancing valves until these temperatures are within a few degrees of each other

Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- Connections between collectors and plumbing pipe are commonly made with synthetic rubber couplings
  - which slide over the header and connecting pipe and are clamped tightly around each by stainless steel bands.
  - To accommodate thermal expansion and misalignment, these couplings are longer than those used between panels

Solar Pool Heating Systems

Collector Installation – Procedures
Piping between Collectors

- A vacuum relief valve may be required on the highest collector group
  - Vacuum relief valves can be installed in more than one group of collectors to facilitate drainage
- The vacuum relief valve must not admit air into the system during pump operation
  - System may be noisy and will consume excessive amounts of chemicals due to constant bubbling
- In such cases, the water flowing down the return pipe may cause a vacuum in that pipe
- Installing the vacuum relief valve on the return end of the highest supply header will keep the valve pressurized until there is a vacuum caused by draining the supply header

Solar Pool Heating Systems

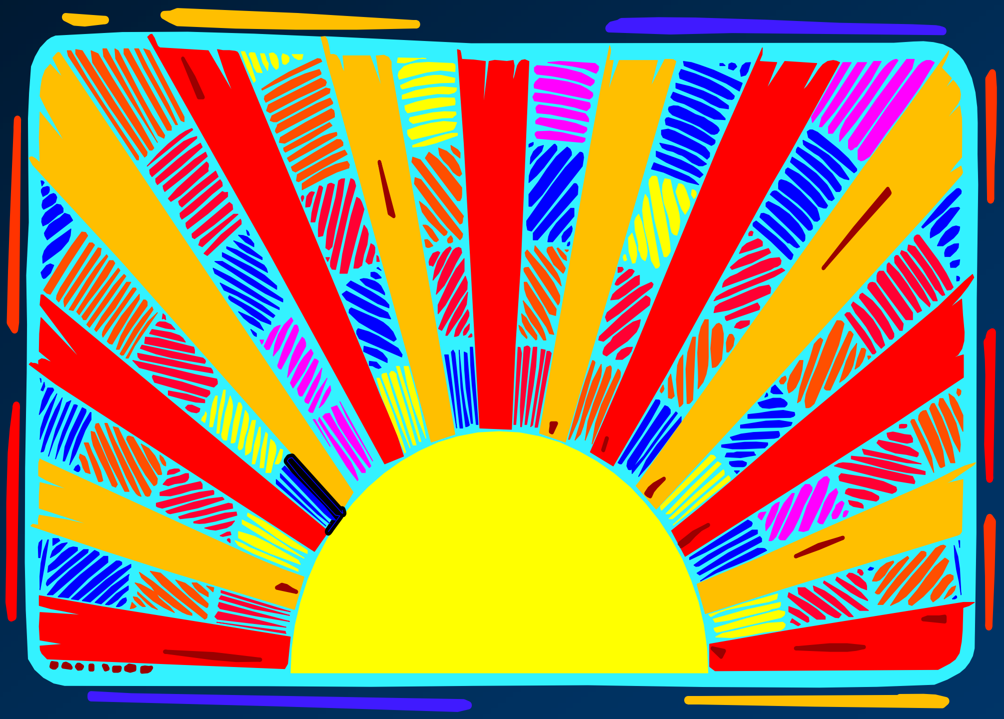
Collector Installation – Procedures
Piping between Collectors

- The tilt of the array must allow complete drainage
- Some pipe layouts will not allow gravity drainage of the collectors
- For example, in piping over the ridge of a roof, the supply and return are higher then the level of the collectors
- This prevents proper drainage of the collectors
- Installing a freeze protection valve on the bottom header of the collector array may allow gravity to drain the panels during freezing conditions

Solar Pool Heating Systems

Collector Installation – Procedures
Flow Control and Safety Devices

- One of the most important components in the flow control system is the control (diverter) valve
- Normally installed in the main filter flow path after the collector feed-line and before the collector return (Figure 7b and 7c)
- Can be a simple manually operated ball valve, for convenience, it is generally operated automatically.



NABCEP Task Analysis

- Identify components specific to a swimming pool heating solar system (2.5)
- Determine solar pool system components' location and system layout and configuration (3.5)

NABCEP Task Analysis

- Determine type, length, and diameter of plastic piping required (7.6)
- Cut plastic pipe to desired length (7.7)
- Glue plastic piping connections (7.8)
- Test glued fittings for leaks (7.9)