FLORIDA SOLAR ENERGY CENTER®

Solar Water and Pool Heating Manual

Design and Installation
&
Repair and Maintenance

FSEC-IN-24

January 2006

1679 Clearlake Road, Cocoa, FL 32922-5703 • Phone: 321-638-1000 • Fax: 321-638-1010
www.fsec.ucf.edu

A Research Institute of the University of Central Florida

Solar Water and Pool Heating Manual

Design and Installation
&
Repair and Maintenance

Florida Solar Energy Center
Cocoa, Florida

HTTP://WWW.FSEC.UCF.EDU

FSEC-IN-24

January 2006

Table of Contents

Prologue: A Brief History of Solar Water Heating

Solar water heating has been around for many years because it is the easiest way to use the sun to save energy and money. One of the earliest documented cases of solar energy use involved pioneers moving west after the Civil War. They left a black pot in the sun all day to have heated water in the evening.

The first solar water heater that resembles the concept still in use today was a metal tank that was painted black and placed on the roof where it was tilted toward the sun. The concept worked, but it usually took all day for the water to heat, then, as soon as the sun went down, it cooled off quickly because the tank was not insulated.

Clarence Kemp of Baltimore patented the first commercial solar water heater in 1891. It was called the Climax. The Climax had several cylindrical water tanks of galvanized iron that were painted black. Kemp insulated the tanks in felt paper and placed them in a glass-covered wooden box for better heat retention. This invention earned Kemp the "father of solar energy in the United States" title.

Solar water heating improved the lives of homeowners, especially during the summer, because it eliminated the need to heat water on the stove. Firing up the stove to heat water warmed the entire house. In the winter, the solar water heater was drained to protect it from freezing, and homeowners resumed heating water on the stove. Kemp claimed the Climax could be used from early April through late October in Maryland. In southern California, it could be used year-round. High-energy costs in California made using free solar energy even more logical. By 1900, 1,600 Climaxes were installed in southern California.

A design by William Bailey in 1909 revolutionized the industry with the first flat-plate collector. The most visible difference in his design was a separate collector and storage tank. The collector had a grid of copper pipes and was covered with glass. He added a metal absorber plate to transmit the solar heat in the box to the water in the pipes. The storage tank was insulated. Since these improvements kept the water warm morning and night, the solar hot water heater was called the Day and Night collector. The system could be connected to a backup gas heater, wood stove or coal furnace. An electric heater could be placed inside the storage tank to heat the water automatically if it dropped below a preset temperature.

Bailey's business grew until a freak cold spell hit southern California in 1913. Copper pipes in the collectors froze and burst when the temperature dropped to 19 degrees Fahrenheit. He solved this problem by placing nonfreezing liquid in the collector pipes. This liquid traveled through a coil in the storage tank to heat the water. He sold more than 4,000 Day and Night heaters by the end of World War I. The peak year was 1920 when more than 1,000 were sold.

Solar hot water heater sales decreased when natural gas prices dropped and gas companies offered incentives, including free installation, to switch to gas. Bailey recognized the trend and used his experience to produce gas water heaters. His company made its last solar water heater in 1941.

California’s gas discoveries nearly put an end to solar water heating there, but this was not the case in Florida where solar was the only way to heat water cheaply. The Solar Water Heater Company was established in Florida in 1923. By 1925, Miami’s population had increased to more than 75,000. Business flourished until Miami’s building boom subsided in early 1926 and a hurricane struck the area in September. The plant closed shortly thereafter.

In 1931, the plant reopened with an improved collector. Charles Ewald changed the wooden box to metal to last longer in Florida’s humid environment. He also insulated the box and replaced the steel tubing with more durable and better conducting soft copper. He discovered that soft copper withstood temperatures as low as 10 degrees Fahrenheit. Ewald added more pipe and placed it strategically for optimum efficiency. His design produced hotter water in greater volume. He called it the Duplex.

He also developed a method of matching the needs of the homeowner with the appropriately sized collector and storage tank. This revived the industry in 1934. The following year, New Deal legislation boosted home building and, in turn, the solar heating business. Inexpensive FHA Home Improvement Loans stimulated the market. By 1941, nearly 60,000 hot water heaters had been sold in Florida. About 80 percent of Miami’s new homes had solar hot water heaters, and more than 50 percent of the city used them. Solar water heaters were also used in north Florida, Louisiana and Georgia and in other parts of the world, including Japan.

No matter how robust, the solar hot water boom wouldn’t last. At the start of World War II, the government put a freeze on nonmilitary use of copper, stalling out the solar hot water heating market. After the war, the rise in skilled labor and copper prices made the collectors less affordable. Electric prices dropped in the ’50s, making electric water heaters more appealing. Installation and initial cost was also cheaper than solar hot water heaters. The tank was automatic too. Solar water heating was not the same bargain anymore in the United States, especially when oil import limits were allowed to surpass 50 percent. A similar scenario happened later in Japan when it began importing oil in the ’60s. The peak year for Japan’s solar hot water sales was 1966.

Throughout history, solar energy remained popular until abundant sources of fossil fuel became available. Interest in solar energy surged during oil embargoes in 1973-74 and 1979.

Federal and state tax incentives led to rising sales in the early ‘80s. Sales flourished, but the industry paid a high price for this brief period of prosperity. A lot of companies entered the solar field just to make money and didn’t care about long-term relationships with their customers. This led to poor installations and gave the industry a bad reputation. After 1985, most of these fly-by-nighters left the solar field.

Equipment has improved since the ’80s. Improvements were precipitated by both certification design review and experienced installers. There are more safeguards available now to ensure competent system design and installation, such as training programs and certification. Training is important. Like any mechanical device, all these systems have to be serviced periodically for optimum operation. The Florida Solar Energy Center now has both collector and system certification programs. The national Solar Rating & Certification Corporation provides collector and system certification, as well as ratings for collectors and systems.

Today, more than 1.2 million buildings have solar water heating systems in the United States. This doesn't include 250,000 solar-heated swimming pools. Japan has nearly 1.5 million buildings with solar water heating in Tokyo. In Israel, 30 percent of the buildings use solar-heated water. Greece and Australia are also leading users of solar energy.

There is still a lot of room for expansion in the solar energy industry. There are no geographical constraints. For colder climates, manufacturers have designed systems that protect components from freezing conditions. Wherever the sun shines, solar water heating systems can work. The designs may be different from the early solar pioneers, but the concept is the same.

Acknowledgements

Principal authors of this manual are Charlie Cromer, Bill Guiney and John Harrison.

This manual is the result of the combined efforts and resources of a number of individuals and organizations. It and previous Florida Solar Energy Center (FSEC) solar water heating manuals have evolved from the original one developed by FSEC in the late 1970s. The current manual also incorporates, into one concise manual, the material that was in the previous “Solar Water and Pool Heating Manual,” the “Solar Water and Pool Heating Design and Installation” and the “Solar Domestic Hot Water Systems Repair and Maintenance” manuals. The individuals involved in writing, reviewing and developing these manuals include former and current FSEC staff members: Subrato Chandra, Charlie Cromer, John Harrison, Bruce Holbaugh, Colleen Kettles, Tim Merrigan, Douglas E. Root and Gerard Ventre. Shelli Keisling converted all of the illustrations into electronic format for the current manual. Melinda Millsap and Mark Thornbloom editorially reviewed the manual and Melinda wrote the brief solar history. Individuals from the Florida solar industry including Ben Bentley, David Bessette and Bob Zrallack were instrumental in critiquing the current manual during its formative stages. They, and other members of the solar industry have always been invaluable reference sources and partners in developing solar energy in Florida.

The Florida Solar Energy Center is extremely grateful to the Florida Energy Office for their contract assistance in developing this and previous manuals. Thanks are also accorded to members of the Florida Solar Energy Industries Association for their assistance in developing the electronic version of the illustrations in this current manual.

The current manual is comprised of various sections and modules within those sections. With this format, revisions can be made simply and quickly, as required. As is the case with every FSEC document, comments on how this manual can be improved are always welcome. Technical comments or inquiries should be addresses to the Florida Solar Energy Center.

Overview

Purpose and Scope

The intent of this manual is to equip the reader with the knowledge and skills needed to design, install, operate and maintain the most common types of solar water heating systems. The manual serves as the textbook for the solar thermal course sponsored and conducted by the Florida Solar Energy Center. It also functions as a study guide for those intending to take licensing or certification exams.

The manual presents an overview of solar thermal applications, provides basic information on the principles of solar energy, reviews solar thermal technologies, and provides detailed instruction on the safe, efficient installation of solar water heating and pool heating systems. The manual is divided into six sections, with each separated into individual modules.

Section 1: Solar Concepts provides a basic understanding of solar thermal concepts

- **Module: Solar Applications** outlines the various applications that can be served by the use of solar water heating systems

- **Module: Solar Basics** provides the reader with an understanding of the physical principles employed in solar thermal technologies.

Section 2: Solar Water Heating Systems focuses primarily on what are commonly called solar domestic hot water systems, which heat water.

- **Module: System Types** describes and illustrates the main types of solar systems, along with variations of each type as well as various freeze protection strategies and design.

- **Module: System Components** details the principal components of solar water heating systems and their function within the system.

Section 3: System Installation covers the steps involved in installing a solar water heating system.

- **Module: Collector Mounting** describes methods for properly placing and installing solar collectors.

- **Module: Component Installation** provides guidelines for the proper and safe placement and connection of the remainder of solar system components.

- **Module: System Installation Checkout and Start-Up**, presents start-up and checkout procedures for systems being installed.

Section 4: Troubleshooting presents structured methods to follow in diagnosing and correcting solar water heating system problems.

- **Module: Problem Assessment and System Checkout** provides guidelines for assessing installed system problems.

- **Module: Troubleshooting Checklist** provides a comprehensive checklist for determining probable causes and the appropriate corrective actions.

Section 5: Solar Swimming Pool Heating Systems is devoted to solar systems that provide heat for swimming pools.

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

Appendix

1. Crome Dome Collector Siting Aid is a tool for determining the best location for solar collectors. Its simplicity and ease of use in the field make it ideal for installation and service personnel.

2. FSEC Simplified Sizing Procedure for Solar Domestic Hot Water Systems is an invaluable guide in sizing solar water heating systems in Florida.

3. Electric Water Heater Circuitry describes the electrical connections in a standard hot water tank with two heating elements. An illustration shows where the high-limit protector is located in the electrical circuits and how two thermostats prevent operation of both heating elements simultaneously.

4. Volt-Ohmmeter (VOM) or Multimeter Operation provides basic information on volt-ohm-meter and multimeter operation and includes a standard temperature and thermistor resistance table for 3,000 and 10,000 Ohm thermistors.

5. Solar System Flow Rates describes two simple methods for checking solar system flow rates.

6. Tools for Service and Repair lists the tools and equipment that field personnel generally need to service a solar system.

Section 1: Solar Concepts provides a basic understanding of solar thermal concepts.

- **Module: Solar Applications** outlines the various applications that can be served by the use of solar water heating systems

- **Module: Solar Basics** provides the reader with an understanding of the physical principles employed in solar thermal technologies.

Section 1
Module: Solar Thermal Applications and Technologies

A wide variety of applications can benefit from the use of solar technologies. Currently, the principal use of solar thermal systems in the United States is for hot water heating and pool heating. This is the main subject area of this manual – domestic solar water heating systems. Nevertheless, the use of solar technologies to provide space heating is also available in colder regions. Internationally, solar technologies are used for a myriad of applications, including standard water and pool heating as well as space heating, crop drying, cooking, and water distillation, to name but a few.

This section provides a general overview of the various applications that can benefit from the use of these technologies.

Solar Thermal Applications

In the United States the use of solar thermal systems is most predominant in the residential market. This has a large impact on local and national energy usage and conservation. Traditionally, the primary use of solar in this sector has been for swimming pool and domestic water heating as well as space heating.

Residential applications




- Domestic hot water
- Swimming pool and spa heating
- Space heating
- Water purification/distillation
- Air Conditioning

Commercial applications




- Hotels
- Schools
- Apartment and condominium complexes
- Recreation areas and campgrounds
- Hospitals/Nursing homes
- Restaurants
- Laundries
- Car washes
- Beverage manufacturing
- Cane sugar refining
- Canning facilities
- Food processing
- Meat packing facilities
- Poultry farms
- Light commercial businesses
- Summer camps
- Recreation areas and campgrounds
- Industrial process heat

Agricultural applications

- Crop drying
- Green houses
- Dairy processing
- Meat processing
- Aqua-culture
- Food processing

Think of some other applications that are not listed above and list them below.

-
-
-
-
-
-
-
-

Once again, this manual concentrates on domestic hot water and pool heating. Nevertheless, as indicated above, other solar thermal applications are quite numerous.

Section 1
Module: Solar Basics

Understanding solar thermal systems requires the knowledge of several energy terms and physical principles. This chapter presents important terms and principles and shows how they apply in solar thermal systems.

Terms and Principles

Insolation is the amount of the sun's electromagnetic energy that "falls" on any given object. Simply put, when we are talking about solar radiation, we are referring to insolation. In Florida (at about sea level), an object will receive a maximum of around 300 Btu/ft^{2}hr (about 90 watts/ft^2 or 950 watts/meter^2) at high noon on a horizontal surface under clear skies on June 21 (the day of the summer equinox).

Sun Path

On the surface of the earth, insolation varies over time because of the planet's daily rotation, tilted axis and elliptical orbit around the sun. Imagine the sky as a dome (sky dome) with the horizon as its edge. From this perspective, the sun's path describes an arc across the sky from dawn until dusk. This perceived path and its variations over time can be plotted as in Figure 1, which shows the annual sun path from the perspective of 28 degrees north latitude. This figure illustrates the seasonal changes in the sun's path for a given location. It shows that the winter the sun rises in the Southeast, sets in the Southwest, has a relatively short path and rises to a shallow 39 degree angle above the horizon at noon. In the summertime, the sun rises in the Northeast, sets in the Northwest, has a longer path and rises to a much higher angle above the horizon.

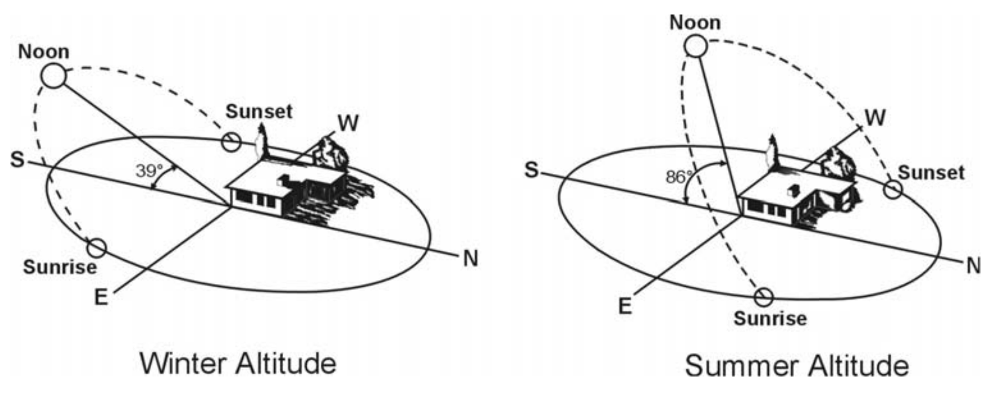


Figure 1. Annual Sun Path for 28º N Latitude (Orlando, Florida)

Atmosphere

The atmosphere absorbs certain wavelengths of light more than others. The exact spectral distribution of light reaching the earth's surface depends on how much atmosphere the light passes through, as well as the humidity of the atmosphere. In the morning and evening, the sun is low in the sky and light waves pass through more atmosphere than at noon. The winter sunlight also passes through more atmosphere versus summer. In addition, different latitudes on the earth have different average "thicknesses" of atmosphere that sunlight must penetrate. Figure 2 illustrates the atmospheric effects on solar energy reaching the earth. Clouds, smoke and dust reflect some solar insolation back up into the atmosphere, allowing less solar energy to fall on a terrestrial object. These conditions also diffuse or scatter the amount of solar energy that does pass through.

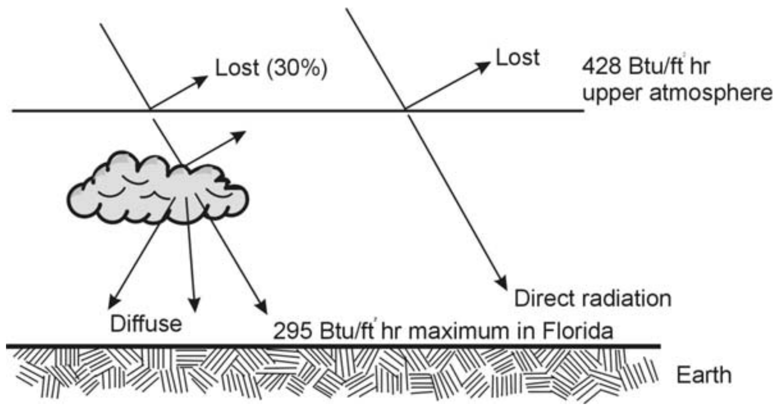


Figure 2. Atmospheric Effects on Solar Energy Reaching Earth

Angle of Incidence

The sun's electromagnetic energy travels in a straight line. The angle at which these rays fall on an object is called the angle of incidence (See Figure 3). A flat surface receives more solar energy when the angle of incidence is closer to zero (normal, perpendicular) and therefore receives significantly less in early morning and late evening. Because the angle of incidence is so large in the morning and evening on earth, about six hours of "usable" solar energy is available daily. This is called the "solar window."

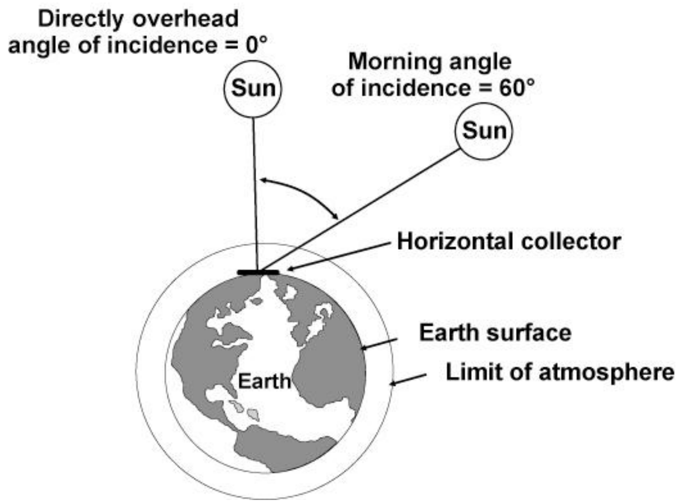


Figure 3. Angle of Incidence

Absorptance vs. Reflectance

Certain materials absorb more insolation than others. More absorptive materials are generally dark with a matte finish, while more-reflective materials are generally lighter colored with a smooth or shiny finish. A golf ball covered with black matte paint placed in sunlight will absorb more solar insolation than a plain white golf ball.

The materials used to absorb the sun's energy are selected for their ability to absorb a high percentage of energy and to reflect a minimum amount of energy. The solar collector's absorber and absorber coating efficiency are determined by the rate of absorption versus the rate of reflectance. This in turn, affects the absorber and absorber coating's ability to retain heat and minimize emissivity and reradiation. High absorptivity and low reflectivity improves the potential for collecting solar energy.

Heat Transfer

Because all natural systems seek a balance, heat always moves from warm (more energy) to cool (less energy). Heat moves by three methods: conduction, convection and radiation.

Conduction

Conduction occurs when a solid material is heated. Molecules exposed to a heat source become energized. These energetic molecules collide with neighboring, less-energetic molecules, transferring their energy. The greater the energy transfer ability of the solid’s molecules, the more energy they can transfer and the better the solid’s conductivity. Copper has high conductivity while glass has low conductivity. If you place a heat source at the bottom of a copper tube and a glass tube at the same time, the top of the copper tube will become hotter quicker than the top of the glass tube.

Convection

Like conduction, convection occurs by molecular motion but in a fluid (such as a gas or liquid), rather than in a solid. When a gas or liquid is heated, the energized molecules begin to flow. On earth, where gravity is a factor, the heated, less-dense fluid flows upward as cooler, more compact fluid moves down. This process of displacement continues as long as the heat source remains.

Radiation

Radiation occurs not by molecular action but rather by emission of electromagnetic waves, generally in the invisible, infrared spectrum. Because radiation does not rely on the presence of matter (molecules) for transport, it can occur in a vacuum. Just as the sun radiates to the earth, a warm object on earth will radiate infrared waves at night to objects in deep space. All objects with heat radiate to objects with less heat that are in a direct path.

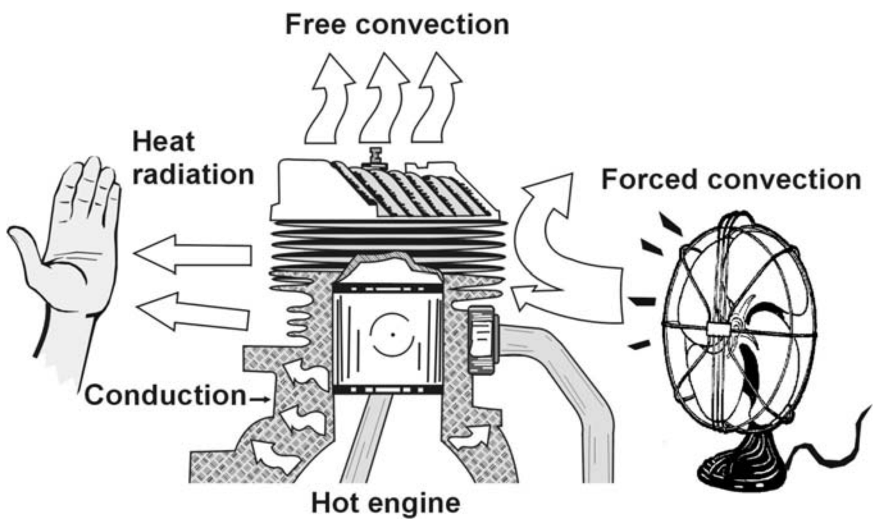


Figure 4. Illustration of Conduction, Convection and Radiation

Temperature Differential or Delta T

The greater the difference in temperature between two points of an object or between two objects, the greater the driving force to move heat from the warmer to the cooler point. This applies whether the heat transfer method is conduction, convection or radiation. Consider the following examples:

Conduction: Applying a 500^{o}F heat source to the bottom of a copper tube will make the top of the tube hotter and it will heat faster than if the heat source were at 250^{o}F.

Convection: A hot air balloon will rise faster if its air is 250° F rather than at 150° F.

Radiation: A camper sitting before a raging bonfire will feel much warmer than a camper sitting by the fire's glowing embers.

Thermal Mass

Thermal mass is the measure of a material's molecules ability to hold thermal energy. The higher the thermal mass, the material's energy capacity, the more efficiently the material can store sensible heat. Rock and masonry are two such materials that have high thermal mass and are solids. Water is a fluid with good energy capacity, making it a good thermal mass medium for energy storage.

Applying the Basics

The purpose of a solar heating system is to collect solar energy, convert it to heat, store the heat, and provide the stored heat for an intended purpose. The efficiency of the system depends on how well the solar basics are applied.

Collecting and Converting Solar Energy

Solar collectors capture the sun's electromagnetic energy and convert it to heat energy. The efficiency of a solar collector depends not only on its materials and design but also on its size, orientation and tilt.

Daily Variations

Available solar energy is at its maximum at noon, when the sun is at its highest point in its daily arc across the sky. The sun's daily motion across the sky has an impact on any solar collector's efficiency and performance in the following ways.

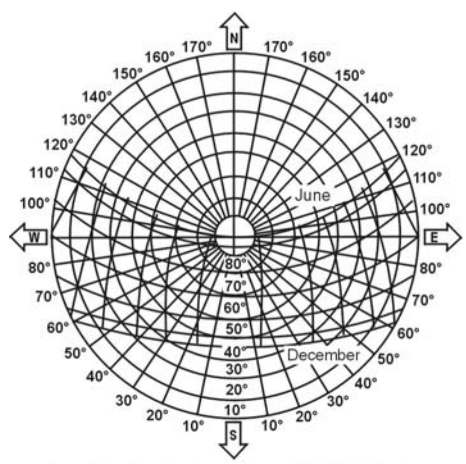
- Since the angle of incidence of the solar energy – measured from the normal (right angle) surface of the receiving surface – changes throughout the day, solar power is lower at dawn and dusk. In reality, there are only about 6 hours of maximum energy available daily.
- The total energy received by a fixed surface during a given period depends on its orientation and tilt and varies with weather conditions and time of day and season.

Aiming the solar device to track the sun's rays to strike it at right angles (normal) all day seems logical, but solar collectors are large and heavy and must be strong to withstand weather conditions. Tracking the sun requires considerably more hardware than does fixed mounting. Most practical designs accept the loss of energy suffered through fixed mounting and use an orientation close to that which collects the most solar energy possible.

Consequently, fixed solar collectors are best positioned to face true south in the northern hemisphere and true north in the southern hemisphere. If the collector will be unavoidably shaded in the morning when installed at its best solar location, it can be oriented slightly west in the northern hemisphere and slightly east in the southern hemisphere.

Seasonal Variations

The dome of the sky and the sun's path at various times of the year are shown in Figure 5 (note that 28˚ is about the latitude of Orlando, Florida). The top illustration shows the paths projected on a flat surface. In mid-June the days are long; the sun rises well north of due east and sets well north of due west. It also passes almost directly overhead (86˚) so that at solar noon on June 21 a horizontal plate will almost collect a maximum amount of solar energy (see Figure 6a). But in December, the sun rises later – south of due east – to a noon elevation of less than 40˚. It sets early on the west-southwest horizon. So, to get about the most solar power at noon in December, a fixed collector should face south and be tilted up at an angle of about 50˚ to the horizontal, as shown in Figure 6b.



Sun Paths in the sky at 28° latitude.

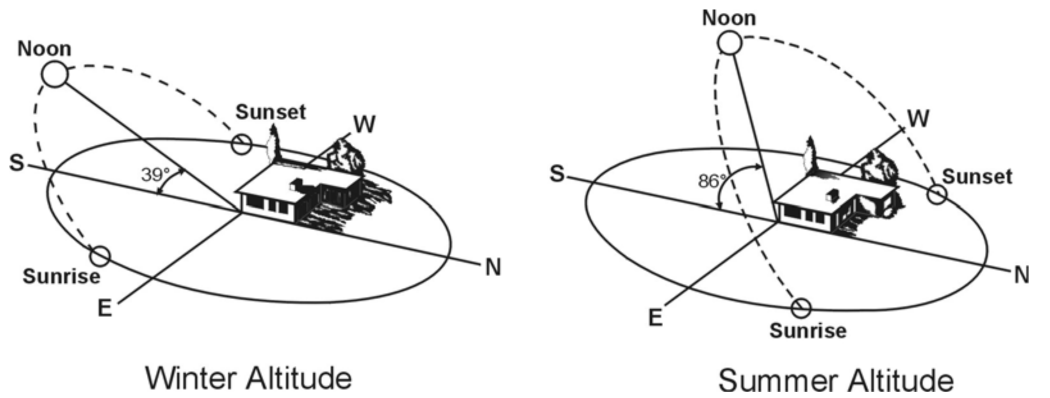


Figure 5. Sun Path Diagrams for 28º N. Latitude

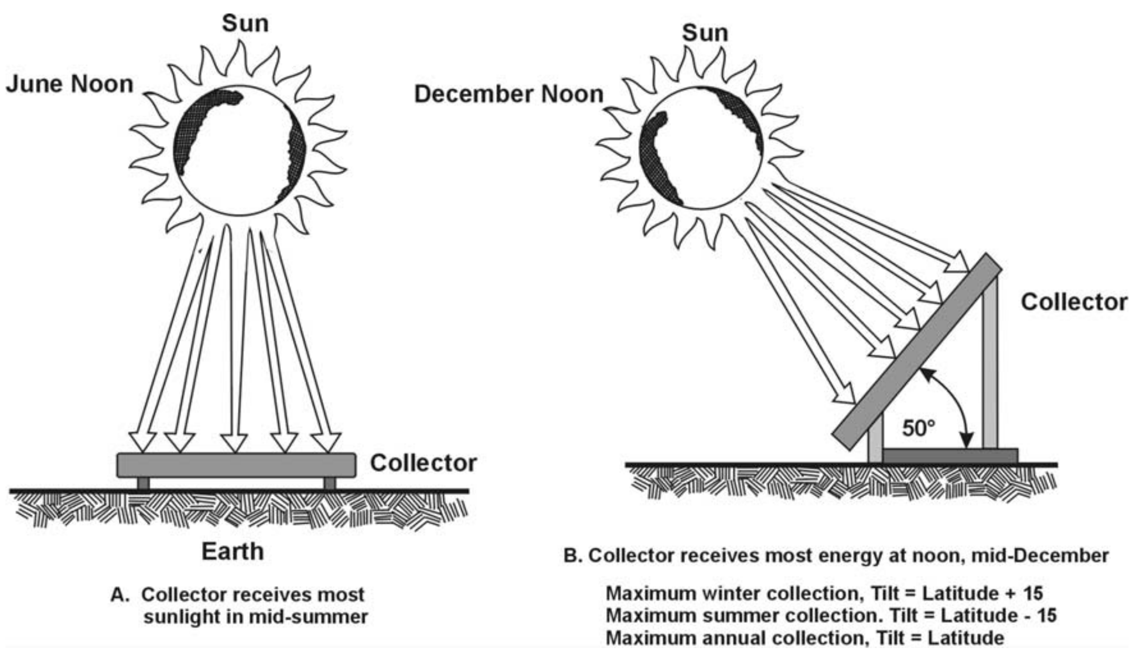


Figure 6a And 6b. Collected Energy Varies with Time of Year And Tilt

For many solar applications, we want maximum annual energy harvest. For others, maximum winter energy (or summer energy) collection is important. To orient the flat-plate collector properly, the application must be considered, since different angles will be "best" for each different application.

Collector Orientation

Collectors work best when facing due south. If roof lines or other factors dictate different orientations, a small penalty will be paid, as shown in Figure 7. As an example: for an orientation 20˚ east or west of due south, we must increase the collector area to 1.06 times the size needed with due south orientation (dashed line on Figure 7) to achieve the same energy output. The orientation angle away from due south is called the azimuth and, in the Northern Hemisphere, is plus if the collector faces toward the east and minus if toward the west. Correction factors may be used to properly size solar collectors which cannot face due south. Closer to the equator, this can change. The lower the tilt of the collector, the less the direction affects it. A collector at 5-10˚ tilt is almost flat to the sun. At 5˚ latitude and at a 5˚ tilt, the collector could be in any direction.

We have assumed that nothing shades the collector during any part of the day. If tall trees, for example, shade a collector until 10 a.m., an orientation west of south (so that the afternoon sun will provide the bulk of the energy collected each day) would enable maximum solar energy collection. Moving the collector or increasing its size will correct disruptions to solar insolation. To help the installer determine shading problems, solar pathfinders are available from several manufacturers, or use the Crome-Dome provided with this manual.

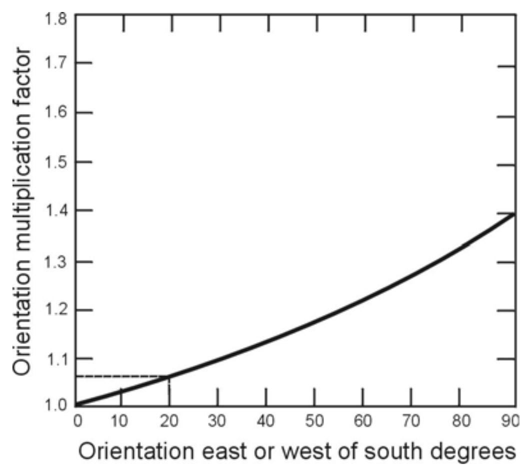


Figure 7. Glazed Collector Orientations

Tilt Angle

The best tilt angle will vary not only with the collector's geographical location but also with seasonal function. Solar water heating systems are designed to provide heat year-round.

Figure 8 below shows results for various collector tilt angles for Central Florida. For the slope angles shown in the figure, we observe these effects:

a) Mounting at an angle equal to the latitude works best for year-round energy use.

b) Latitude minus 15˚ mounting is best for summer energy collection.

c) Latitude plus 15˚ mounting is best for winter energy collection.

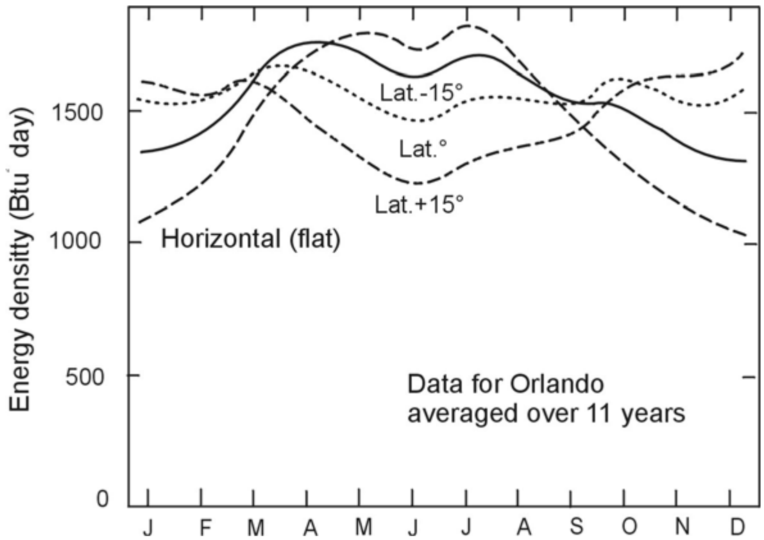


Figure 8. Various Collector Tilt Angles

Table 1 illustrates the effect of various tilt angles on a flat-plate solar collector installed in Miami, Florida.

Table 1. Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m^2/day average) in Miami, Florida (25.80˚ N. Latitude)

Tilt Angle	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0	3.5	4.2	5.2	6	6	5.6	5.8	5.6	4.9	4.4	3.7	3.3	4.8
Latitude -15	4.1	4.7	5.5	6.2	5.9	5.5	5.7	5.6	5.1	4.7	4.2	3.9	5.1
Latitude	4.7	5.2	5.7	6.1	5.6	5.1	5.4	5.5	5.1	5.1	4.7	4.5	5.2
Latitude +15	5.0	5.4	5.6	5.7	5.0	4.5	4.8	5	4.9	5.1	4.9	4.9	5.1
90	4.1	3.9	3.4	2.6	1.9	1.6	1.7	2.1	2.7	3.5	3.9	4.1	3

Methods exist to move a collector so the sun's rays strike it at a right angle all day and in all seasons. Use of such sun-tracking mechanisms increase the amount of energy a collector receives, but it also increases the system's cost, complexity and future maintenance requirements. Most practical designs accept the loss of energy suffered through fixed mounting and use an orientation and tilt to collect the most usable solar energy possible.

Therefore, for year-round use, a collector tilt of about 25˚ for south Florida or about 30˚ in North Florida works best. On a final note, installers must also keep in mind the aesthetics of the collector mounting on the plane of the roof.

Heat Storage

Most solar thermal systems employ a material with high energy capacity to store sensible heat until it is needed for a specific purpose. Water, masonry and even iron are all such thermally massive materials with high energy capacities. When the purpose of the solar thermal system is to provide heated water, the water itself is the thermal mass that stores the heat generated by the solar collector.

For these solar water heating systems, the water itself may be the fluid heated in the collector and then delivered directly to the tank. In areas where freezing temperatures are common during winter, the heat collecting fluid may be glycol or another heat transfer fluid with high energy capacity that can withstand freezing temperatures. Such systems employ heat exchangers at the storage tank to transfer the heat from the collector fluid to the potable water.

In solar water heating systems, the storage is sized with generous proportions to hold as much heated water as may be needed for a given purpose during times of low solar insolation. The tanks are also highly insulated to reduce heat losses.

Further from the equator, inlet water temperatures are colder, while in many cases, the insolation may be close to the same during some periods of the year. On a given day, if the amount of insolation is about the same, one might think solar systems in Toronto or Miami would perform about the same. The total heat energy collected and stored in the tank may be about the same, but the end-of-the-day tank temperatures will be different.

The Toronto storage tank will be colder than the Miami storage tank due to the difference in cold water supply temperatures. The cold water supply water temperature in Miami is approximately 75˚F, while the cold supply in Toronto is approximately 45˚F. More total solar energy is required to increase the Toronto system to the same end-of-the-day tank temperature.

To achieve the same end-of-the-day tank temperatures in Toronto you must increase the size of collector area to increase the energy gain of the system. Simply put, more collector is required in order to increase the total degrees of the water being heated.

Additional System Considerations

To meet its intended purpose, a solar thermal system must meet criteria beyond simply collecting and storing solar energy.

Safety

A solar thermal system must not contaminate the medium used to store or provide the system's energy output. For example, solar water heating systems must not contaminate water that may be used in food preparation or in human contact activities. For this reason, solar water heaters with heat exchangers frequently employ two walls to isolate the potentially dangerous heat collecting fluid from the water to be heated.

Mechanical safety must also be assured in designing and installing solar collectors. A 4-by-10-foot solar collector can act like an airplane wing in strong winds, so it must be structurally well connected and securely attached to its mounting surface.

Affordability

Affordability can be defined as performance balanced by price. A solar thermal system with collectors that track the sun's path will perform better than one with fixed collectors. However, the tracking mechanisms can double the cost of the system. In the same way, a solid gold absorber will perform better than a copper one, but the cost would be astronomical. To be affordable, a solar thermal system must balance performance and cost. Because solar thermal systems produce Btus. Btu per buck (Btu/$) is a good measure of affordability.

Materials Used

Materials for solar energy systems must be chosen carefully. The most important factors are safety, performance, durability and cost.

The materials must retain their shape and strength during repeated thermal expansion and contraction–all the while being exposed to the weather. Collector materials lead hard lives. The collector is exposed to wind, rain, hail, temperature extremes and ultraviolet radiation. Untreated plastics, woods and synthetic boards deteriorate rapidly under such conditions. Even steel must be protected by plating, galvanizing or painting. The collectors must be able to tolerate stagnation temperatures. This can be as high as 400°F for some solar collectors. Durability is important in all materials used in a solar system because the cost effectiveness varies directly with their life expectancy.