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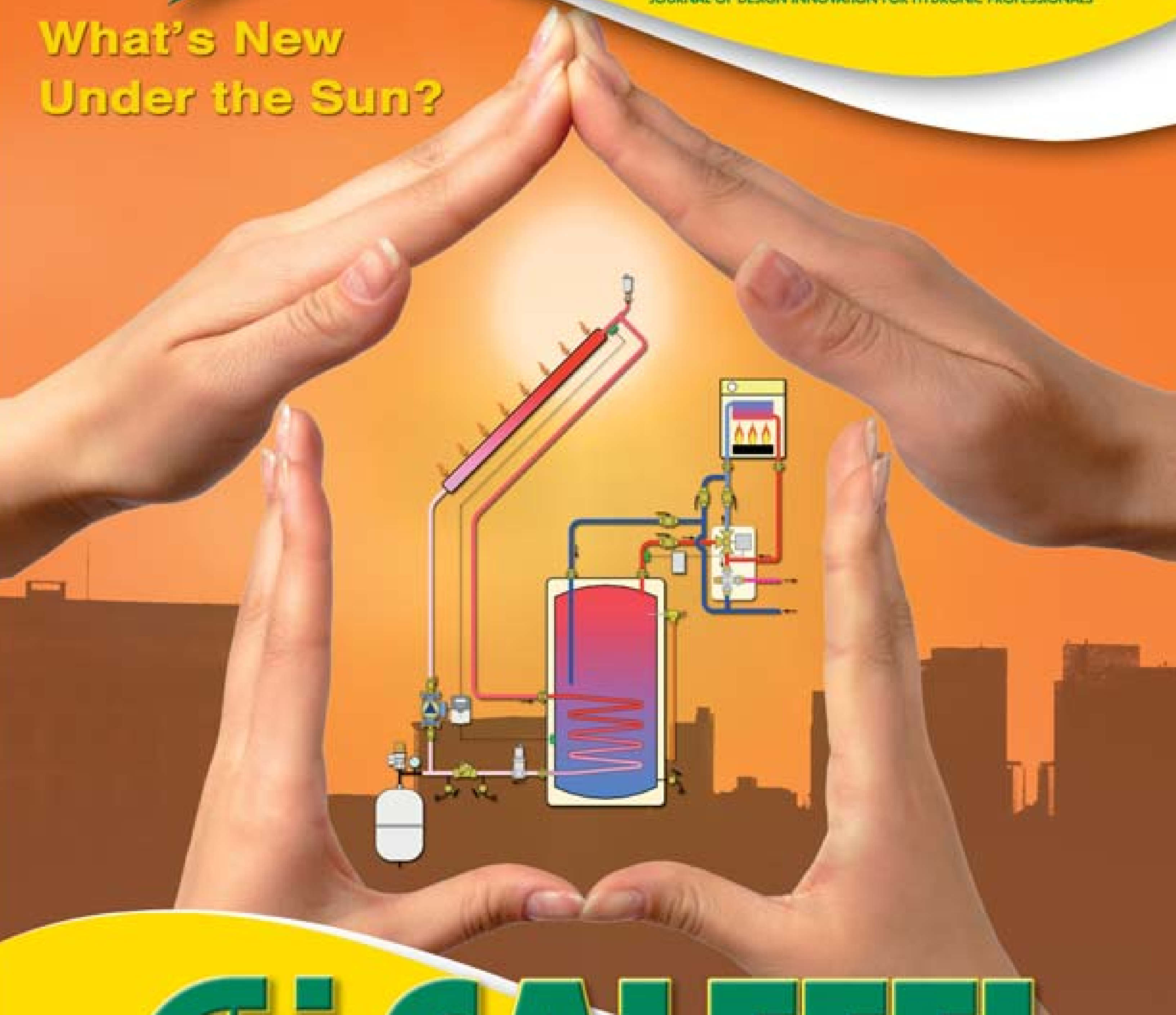
idronics™

JOURNAL OF DESIGN INNOVATION FOR HYDRONIC PROFESSIONALS

What's New Under the Sun?



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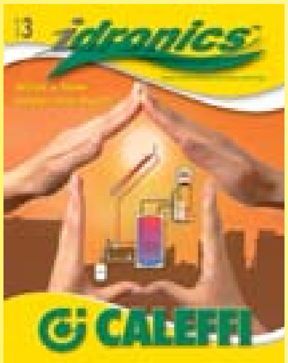

A Technical Journal
from
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Dear Hydronic Professional,

Welcome to the 3rd edition of idronics, Caleffi's semi-annual design journal for hydronic professionals.

The "green" state of mind is rapidly spreading across North America. Soaring fossil fuel costs, environmental issues and national security concerns are all raising interest in alternative energy technologies. An especially popular topic is solar heating, the subject of this edition of idronics.

Caleffi has developed and marketed solar heating products in Europe and other parts of the world for many years. In most of these regions, the high cost of fossil fuel and heightened sense of environmental responsibility has made solar heating a well-accepted standard rather than rarely used alternative.

We see a similar trend quickly developing in North America. At our North American headquarters in Milwaukee, each week brings numerous inquiries from plumbing and heating professionals on how to design and install solar heating systems. These inquiries demonstrate a need to take the "mystery" out of solar heating, and give these professionals the know-how and confidence to pursue this growing opportunity.

That's the goal for this issue of idronics. It begins with a primer on solar heating fundamentals, then presents a wide spectrum of design concepts and hardware options for solar water heating and space heating. For the seasoned solar professional, it provides innovative design solutions to consider for future applications.

So whether you're a plumber who wants to install solar water-heating systems, or a veteran designer of commercial solar space-heating systems, we trust this issue of idronics will be a useful and handy reference.

If you would like to receive future editions of idronics free of charge, please send in the attached reader response card, or register online at www.caleffi.us. You can also download all previous issue of idronics as PDF files from this Web site. Feel free to let us know if this issue of idronics has been useful to you, as well as topics you would like to see discussed in future issues.

Sincerely,

Mark Olson
General Manager,
Caleffi North America, Inc.

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WHAT'S NEW UNDER THE SUN?

Solar energy has been used in North American buildings for decades. The first commercial solar water-heating device sold in the United States was patented in 1891. However, widespread use of solar energy in North America did not transpire because fossil fuels were readily available and relatively inexpensive throughout the industrial expansion period following World War II.

This situation quickly changed in the later 1970s following the Arab oil embargo. At that time, scores of manufacturers delivered products to the North American market to capitalize on the fervor to replace conventional energy sources with renewable energy. Although some of the solar heating and domestic hot water systems installed during this time are still functioning today, many have long since failed, been abandoned or were removed.

The lack of standards and regulation during America's first "solar era" allowed previously untested hardware and design concepts to quickly enter the market. Government tax incentives stimulated this trend. The market enjoyed rapid growth during the early 1980s and then slowly succumbed to a combination of market forces (expiration of government tax credits and declining energy prices), as well as failure of some products to withstand the test of time. Although a few pockets of activity remained for solar pool heating and domestic water heating in the sunny southern markets, widespread national interest in solar heating was virtually non-existent during the late 1980s and 1990s as North Americans remained complacent in the face of low energy prices

TIMES HAVE CHANGED:

Today, North Americans are facing some of the largest energy price increases in history. Crude oil is selling at record levels, and energy cost reduction has again become a high priority for homeowners as well as commercial building owners. The rapid expansion of solar heating technology in Europe is quickly making its way to North America and other areas of the world. Ecological concerns over global warming, as well as national security issues associated with oil importation, are also factoring into energy supply decisions. In short, North America and other industrialized countries are poised to enter an era where energy conservation and use of renewable energy sources will play a major part in their future prosperity.

Here are a few facts that help us realize the potential impact of renewable energy, now and in the future:

- In one second the sun releases more energy than has been used by mankind since the beginning of recorded history.
- In one hour more sunlight falls on the earth than what is used by the entire population in one year.
- In 2006 the renewable energy industries in the United States generated nearly $40 billion in gross revenue, while creating nearly 194,000 jobs. *

Source: Management Information Services, Inc. and American Solar Energy Society, 2007.

- A major international oil company predicts that renewable energy will supply 50% of the world energy by 2040.

Source: NASA

In the years since the first North American solar era, manufacturers, both domestic and abroad, have significantly refined product offering. Modern materials combined with new production methods now provide products with long service lives. Improved control systems provide greater solar collection efficiency. Modular piping systems speed installation and reduce "one-of-a-kind" installations. In short, North Americans are poised for a new "sunrise" in the use of solar energy.

This issue of idronics will introduce you to the basic terminology and system concepts for modern collection and usage of solar energy. Although solar energy usage will be briefly discussed in a wide context, the bulk of the discussion focuses on active solar thermal applications.

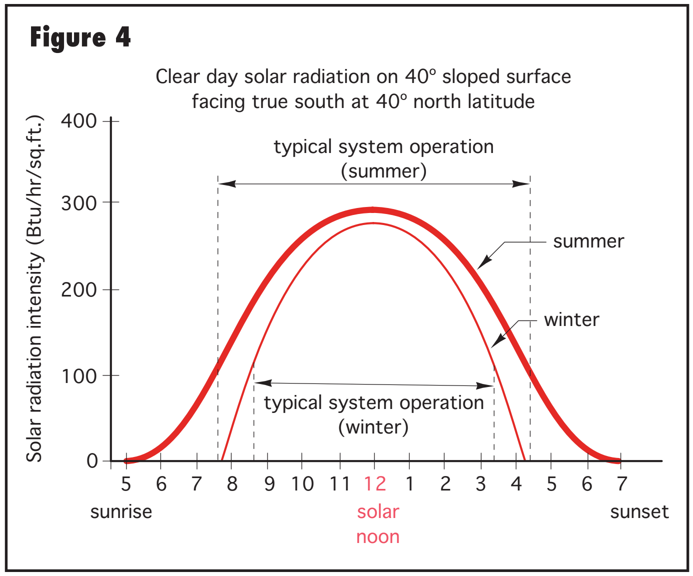
CHARACTERISTICS OF SOLAR RADIATION:

Technically, solar radiation is a form of electromagnetic radiation that's fundamentally similar to radio waves, X-rays, and even "radiant heat" emitted by a warm floor. Although solar energy is produced by nuclear reactions at the sun, its transmission through space to earth has nothing to do with nuclear radiation.

What distinguishes solar radiation from other types of electromagnetic radiation is its wavelength. Approximately half of the energy in solar radiation lies within wavelengths that can be sensed by the human eye (e.g., visible light). The remaining energy lies in the infrared and ultraviolet portion of the electromagnetic spectrum, as shown in figure 3.

The intensity of solar radiation just outside the earth's atmosphere is approximately 429 Btu/hr/ft². This is more than 10 times the typical maximum output of a radiant floor panel. However, the intensity of this radiation is significantly reduced before it reaches the earth's surface due to absorption by gases, vapors and dust particles in the atmosphere. Geographic location on the earth, as well as time of day and time of year, greatly affects the intensity of solar radiation reaching the earth's surface. Figure 4 shows the intensity of clear day solar radiation on a south-facing surface sloped at 40° above horizontal and located at 40° north latitude.

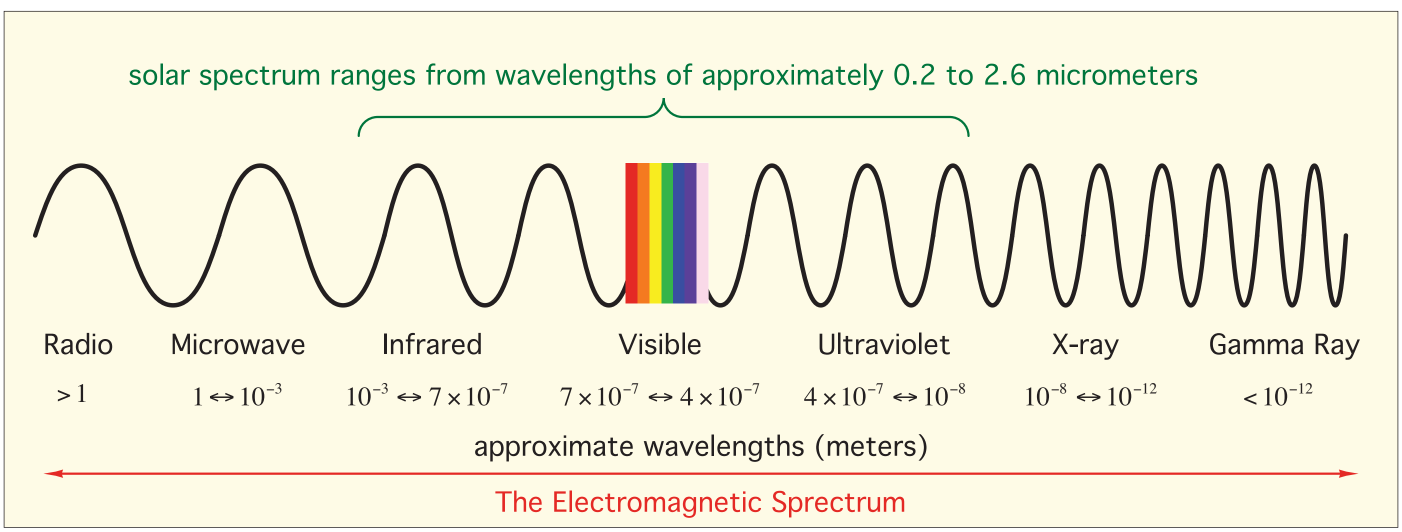
Figure 4



On a clear day, solar radiation is most intense at solar noon (e.g., that time of day when the sun is highest in the sky and directly above a polar north/south line).

Before striking the earth's atmosphere, solar radiation travels in straight paths. This is called "direct" solar radiation. On a clear day, the majority of solar radiation striking the earth's surface is direct radiation. Because it

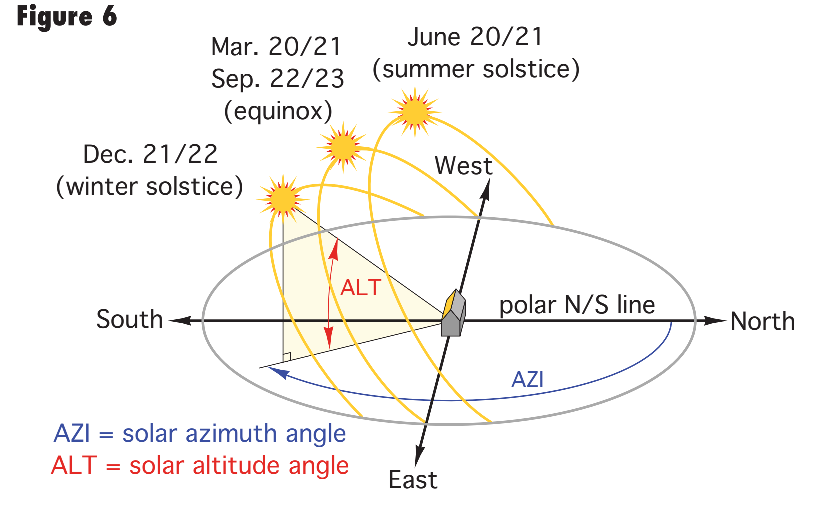
Figure 3



travels in straight lines, direct radiation is easy to reflect using polished silver or aluminum surfaces, or to focus using parabolic mirrors.

If there were no atmosphere, nearly all the solar radiation reaching the earth's surface would be direct radiation. However, the gas and vapor molecules in the atmosphere create a very different scenario. They reflect a significant portion of the incoming direct radiation in every direction. The result is called "diffuse" solar radiation. Its presence is the reason we see the sky and objects around us much differently than how objects are seen in space where no atmosphere exists. The vast majority of solar radiation reaching the earth's surface on cloudy days is diffuse radiation. Because diffuse radiation comes from the entire sky dome above us, it cannot be easily focused using mirrors or other reflecting surfaces.

Figure 6



SOLAR ANGLES:

The earth revolves once each day around an axis that passes through the North and South poles. That axis is tilted 23.44° with respect to the orbital plane of the earth around the sun, as shown in figure 5.

The tilt of the earth's axis is called the *declination angle*. It's the reason that day length changes as the earth makes its annual orbit around the sun. It also significantly affects the intensity of solar radiation striking a fixed surface at any location on earth. We observe this effect as a change in the sun's path across the sky, as seen in figure 6.

The sun's position in the sky can be precisely described using two simultaneously measured angles. The *solar altitude angle* is measured from a horizontal surface up to the center of the sun. The *solar azimuth angle* is measured starting from true north (0º) in a clockwise direction (i.e., true south would have a solar azimuth of 180º). These angles vary continuously as the sun moves across the sky. At any given time they are also different

Figure 5

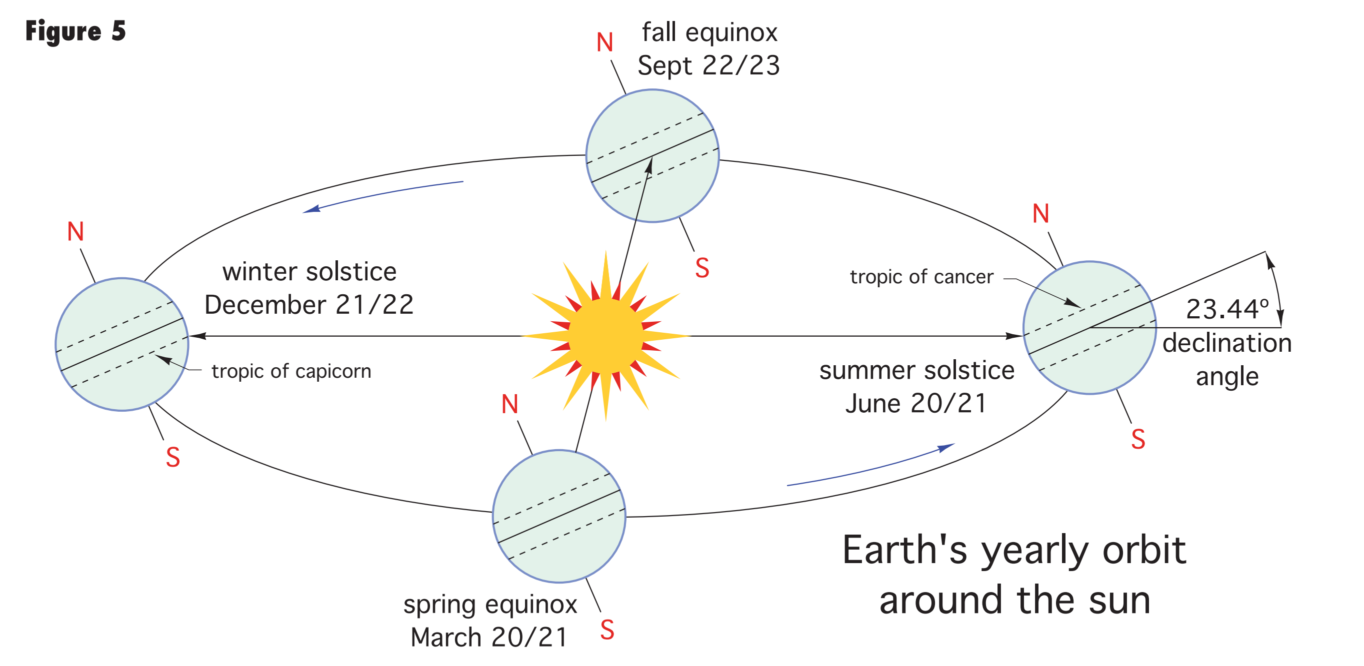
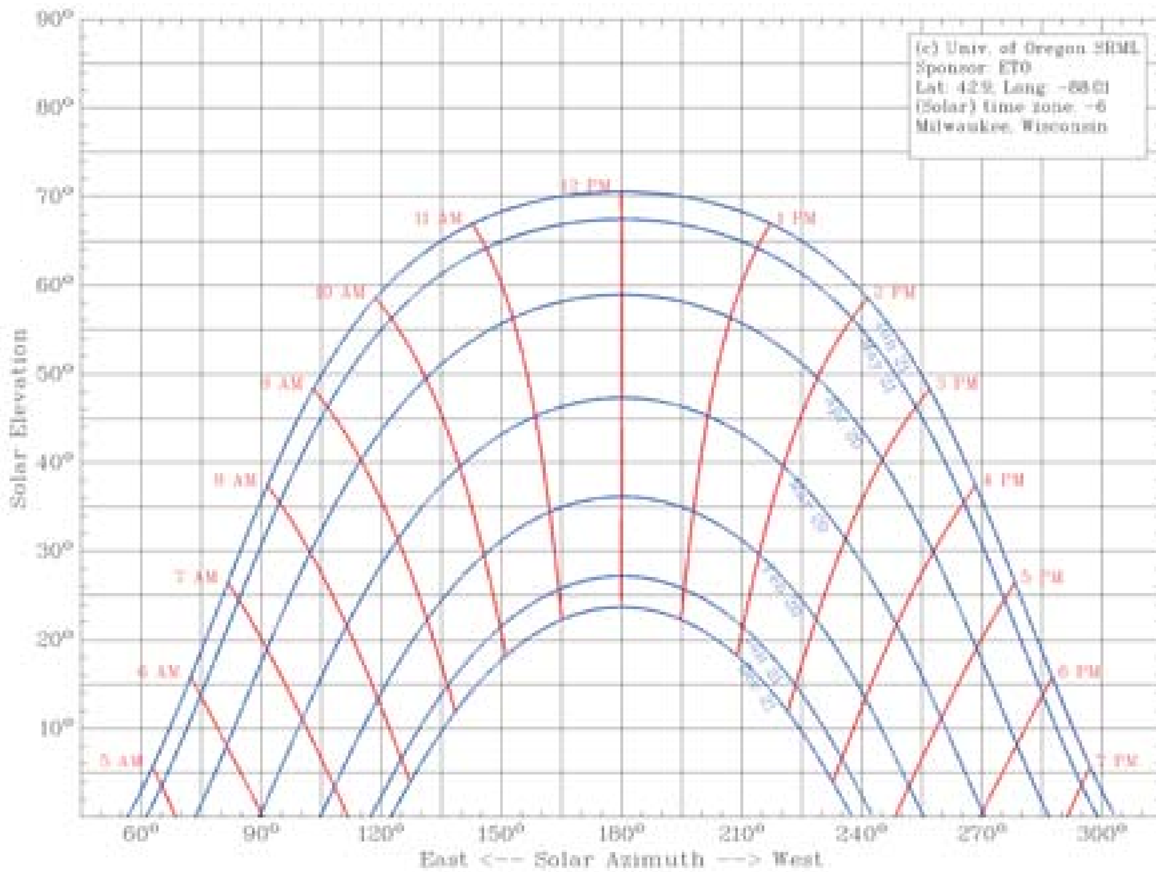


Figure 7



Source: National Geophysical Data Center

at different latitudes and longitudes. These angles have been precisely measured, and when needed, can be calculated for any time and location on earth. Figure 7 shows a solar path diagram indicating the solar altitude and azimuth angles for Milwaukee, Wisconsin, at 42.9° North Latitude. The calculator at the following Web site can be used to generate a solar path diagram for any location or time: http://solardata.uoregon.edu/SunChartProgram.html.

LOCATING TRUE SOUTH:

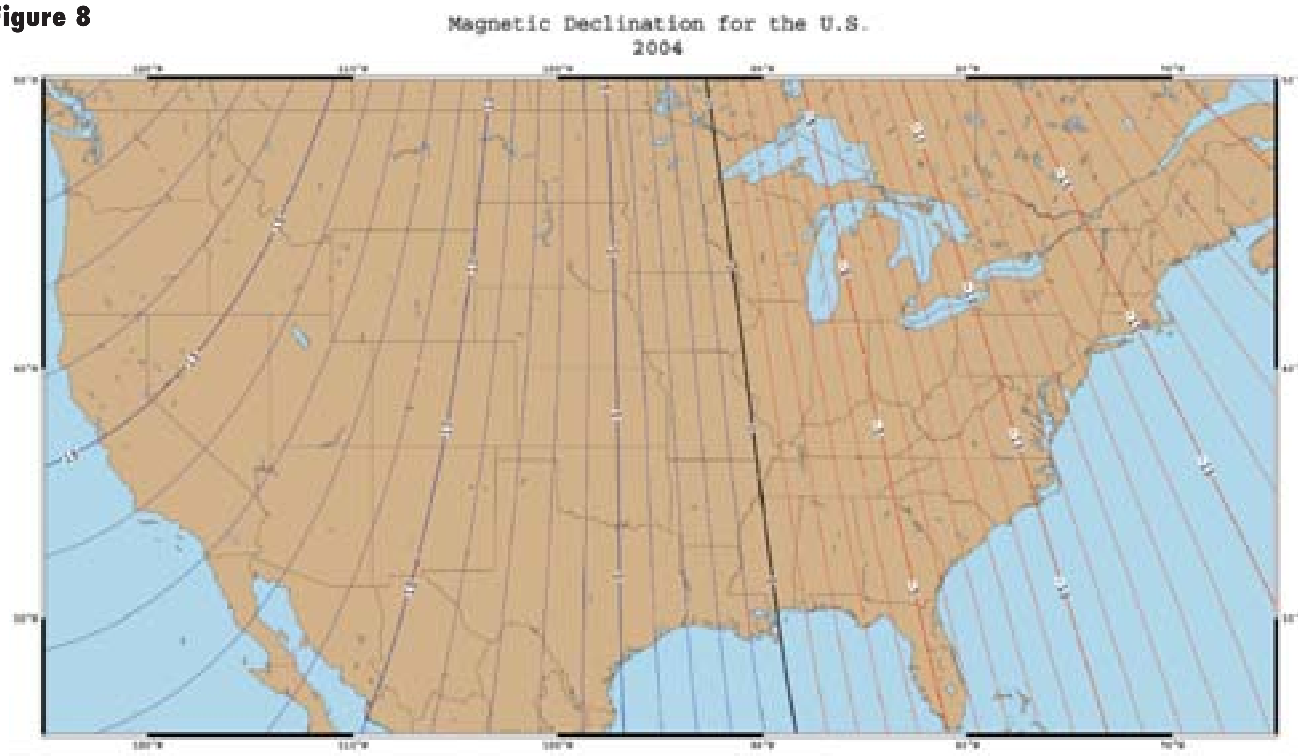
Solar azimuth angles are always referenced to a "true" north line. This is a line at the earth's surface that's exactly parallel with the earth's polar axis. Because the earth's magnetic field is not aligned parallel with its polar axis, there are locations within the continental United States where the needle of a compass can point as much as 20° east or west of a true polar North/South line.

The isogonic chart shown in figure 8 shows the deviation of a magnetic compass needle from true north. For example, in Boston, the isogonic chart indicates a deviation of approximately 15.5° west. This implies that true *south* is actually 15.5° west of the indicated compass south. In this case, solar collectors oriented to an uncorrected south compass direction would actually be facing approximately 15.5° east of true south.

The deviation between compass indicated north/south and "true" north/south is called magnetic declination. It can be precisely determined for any location based on latitude and longitude using the calculator at the following Web site: http://www.ngdc.noaa.gov.

The deviation between a true north/south line and magnetic north/south line varies slightly over time. This variation is caused by the magnetic properties of magma flowing deep beneath the earth's crust. Because of this, isogonic charts are typically dated. Fortunately the deviations over time are relatively minor and will have essentially insignificant impact on solar collector installation and subsequent performance.

Figure 8



TYPES OF SOLAR THERMAL SYSTEMS:

Any device or combination of components intended to convert solar radiation into usable heat can be classified as a solar thermal system. Our discussion of such systems will be limited to those intended to heat buildings and/or domestic water.

In a broad context, solar thermal systems can be classified as either passive or active.

PASSIVE SOLAR THERMAL SYSTEMS:

Solar thermal systems that collect solar radiation and deliver it to the heating load without need of fans or circulators are called *passive* systems. A building with suitable amounts of south-facing windows combined with internal thermal mass (concrete walls, floors or water-filled containers) is itself a passive solar thermal system. When properly designed, such a building can reduce the need for heating energy from conventional sources by 50% or more. Passive solar buildings in sunny climates can achieve even higher fuel savings, all without the need of fans or circulators.

There are many ways of constructing passive solar buildings. These include direct gain through windows, attached sunspaces and trombe walls. One of the simplest is a direct gain passive building, as illustrated in figure 9. Light from the low wintertime sun shines through south-facing windows. Much of the light is instantly

Figure 9

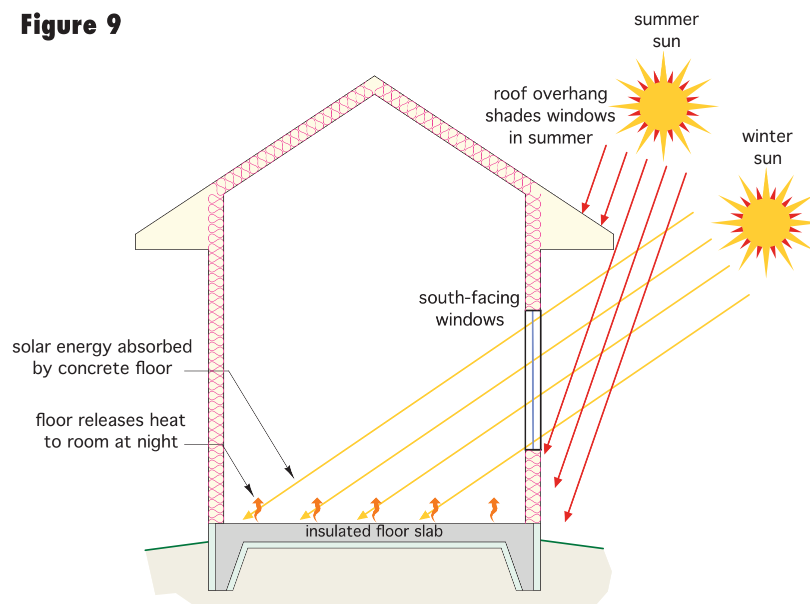
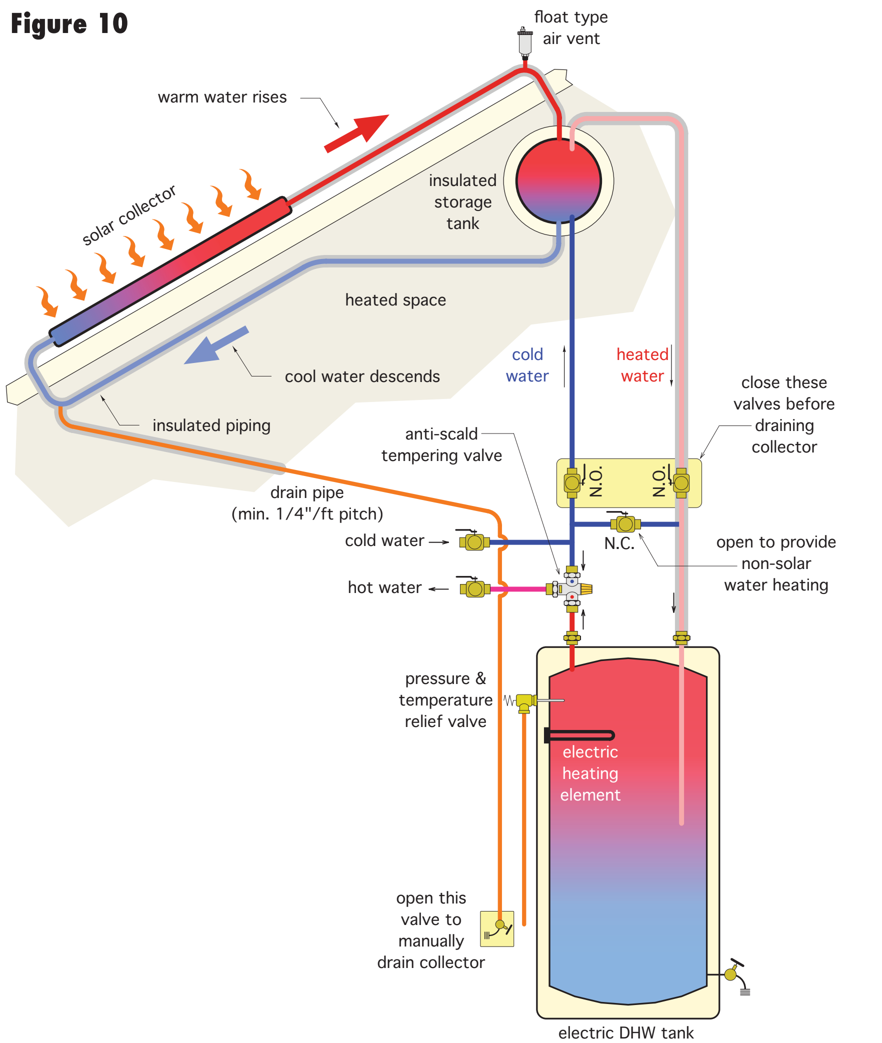


Figure 10



The warmer (lighter) water rises as the cooler (heavier) water descends. This is called "thermosiphoning," and it conveys heat from the collector to the storage tank without need of a circulator. Thermosiphoning continues as long as water in the collector is warmer than water in the storage tank. As sunlight diminishes, the collector cools to a temperature below that of the storage tank, and the flow stops. As hot water is used in the building, cool water enters the storage tank to replace the exiting hot water. This type of passive water-heating collector must be drained if freezing weather is expected. It is used primarily in climates with minimal, if any, freezing conditions.

In the system shown, heated water from the solar storage tank is routed to the inlet of an electric water heater, where its temperature is increased to the desired setpoint (when necessary). A thermostatic mixing valve on the outlet of this water heater prevents high temperature water from reaching the building's fixtures. High water temperatures are possible in almost any type of solar water heating system during prolonged sunny weather, especially if hot water demand is low.

converted to heat as it strikes the floor and other objects in the room. Some of this heat immediately raises the interior air temperature. The rest is absorbed by the concrete floor slab and other objects in the space. The absorbed heat is later released into the room as the interior air temperature cools. Properly proportioned roof overhangs shade the south-facing windows during summer to limit solar gains.

There are also passive solar thermal systems for heating domestic water. An example of one such system is shown in figure 10.

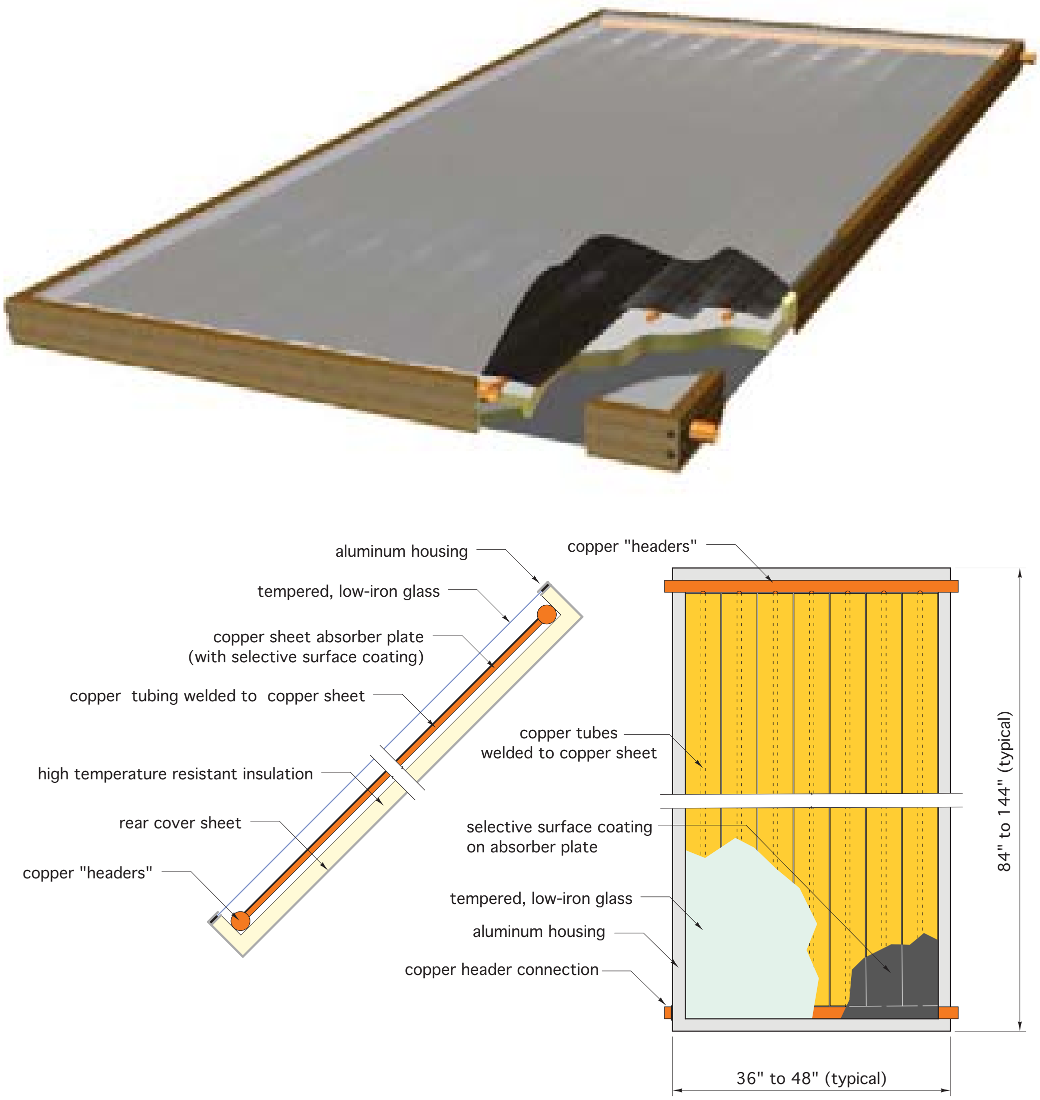
This system consists of an insulated storage tank located above a sloped solar collector. The tank may be located inside or outside. When warmed by incoming sunlight, water in the solar collector expands. Its reduced density compared to cooler water in the bottom of the storage tank creates a gentle circulation effect.

ACTIVE SOLAR THERMAL SYSTEMS:

Any system that uses a blower or circulator to move air or a liquid through the solar collector(s) is classified as an active solar thermal system. As with passive systems, there are countless variations in design for both space heating and domestic water heating. These variations all have strengths and limitations. Several will be discussed in later sections. However, before discussing *systems*, we'll examine options for one of the most important components in such systems — solar collectors.

Nearly all liquid-based active systems use either a "flat plate collector" or "evacuated tube collector."

Figure 11



FLAT PLATE COLLECTORS:

An example of a flat plate solar collector is shown in figure 11.

The principal component in this type of collector is the absorber plate, which is usually an assembly of copper sheet and copper tubing. The top surface of the absorber plate is coated with dark colored paint or electroplated “selective surface” coating that absorbs the vast majority of solar radiation striking it. The instant solar radiation strikes this surface it is converted to thermal energy (e.g., heat). The copper sheet acts as a wick to conduct this heat toward the copper tubing that is welded or otherwise bonded to the sheet. Heat moves across the copper sheet toward the tubes because the fluid flowing through the tubes is cooler than the absorber sheet. This fluid absorbs the heat and carries it out of the collector.

To minimize heat loss, the absorber plate is usually housed in an enclosure made of aluminum and capable of withstanding many years of exterior exposure. The sides and back of this enclosure are insulated with materials capable of withstanding temperatures in excess of 350ºF, which might occur if the collector is exposed to intense sunlight without fluid flow through its absorber plate.

The upper surface of the enclosure is usually tempered glass with a low iron oxide content. Tempered glass can withstand high thermal stress as well as potential impact from hailstones or other objects. Low iron oxide content glass minimizes absorption of solar radiation as it passes through on its way to the absorber plate.

EVACUATED TUBE COLLECTORS:

Another type of active solar collector consists of several glass tubes, each of which has concentric inner and outer walls. The annular space between these glass tubes has been evacuated of air and thus acts like a Thermos® bottle. Convective heat transfer between the inner and outer glass tubes is essentially eliminated. A coated copper absorber strip with attached tubing is located within the inner glass tube, as shown in figure 12.

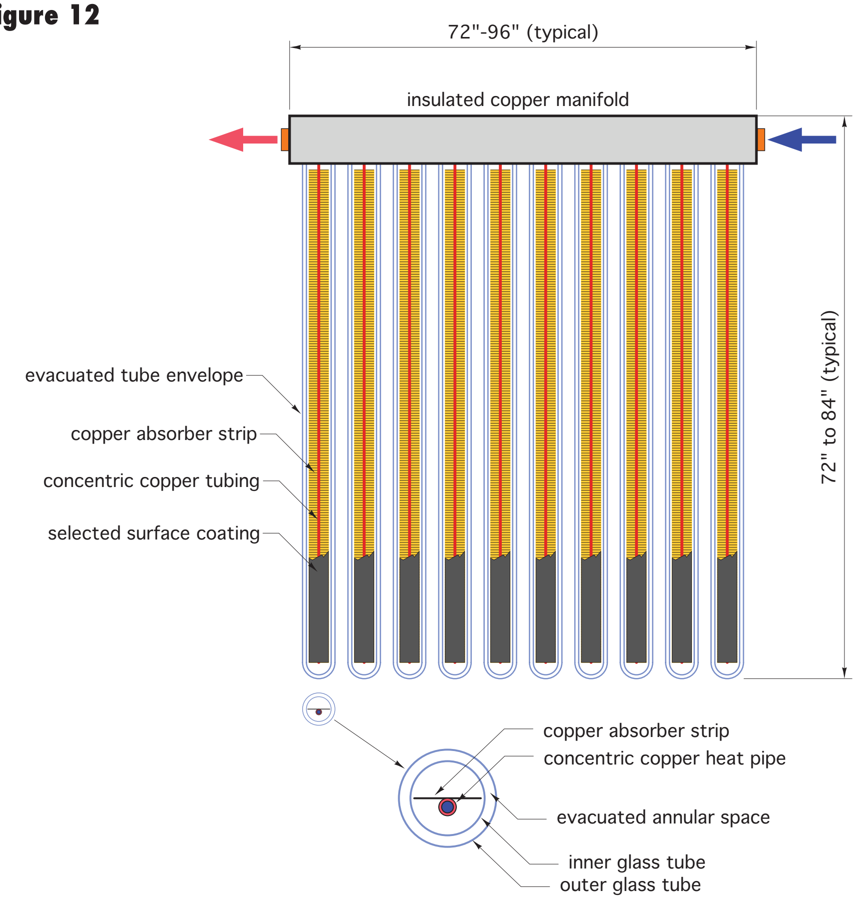
Most current-generation evacuated tubes have a specialized fluid sealed within the internal copper tubing. When heated, this fluid changes from liquid to vapor and rises toward the top of the tube. It then passes into a small copper capsule that fits tightly into a manifold assembly at the top of the collector. Heat conducts though this copper capsule into fluid circulating along the manifold. The fluid sealed within the evacuated tubes never contacts the fluid in the manifold. As heat is released from the fluid within the evacuated tube, it condenses back to a liquid and flows back to the bottom of the tube ready to repeat the cycle.

Figure 13

Photo courtesy of Hi Valley Supply

A roof-mounted array of evacuated tube collectors is shown in figure 13. The manifold can be seen at the top of the evacuated tubes.

Figure 12



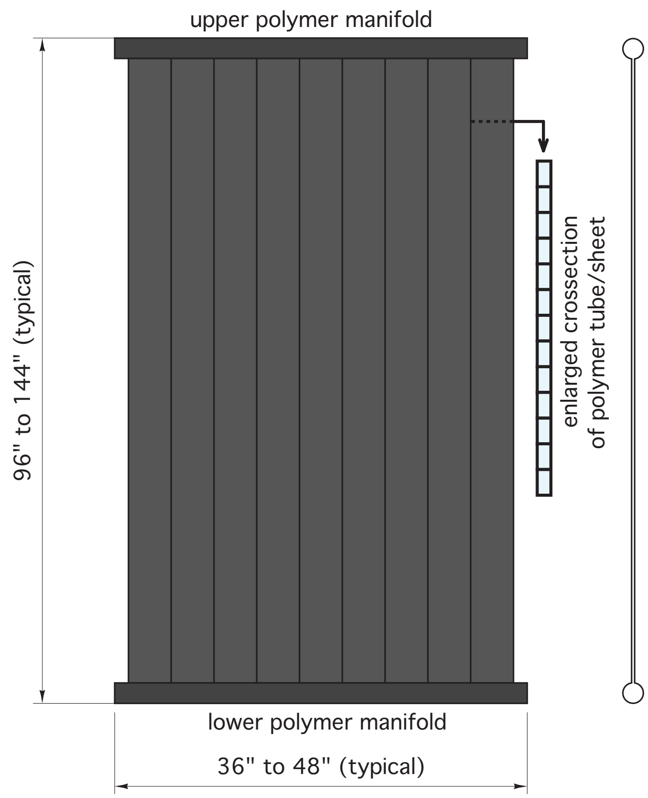
SOLAR COLLECTORS FOR POOL HEATING:

Pool heating is often one of the most economically viable forms of solar energy utilization (assuming it displaces what would otherwise be conventional fuels used to heat the pool).

Most solar pool-heating systems use an unglazed and uninsulated flat plate collector. This is acceptable because the absorber plate operates very close to — if not lower than — ambient air temperature. Under such conditions, the absorber plate loses very little, if any, heat due to convection, and thus does not need an enclosure to prevent heat loss.

The absorber plate is usually constructed of UV-stabilized polymers compatible with pool water chemistry. It consists of an upper and lower header with several polymer

Figure 14



tube/plate assemblies thermally fused in between, as illustrated in figure 14.

Pool-heating collectors have a very high wetted surface area to compensate for the lower thermal conductivity of the polymer material versus copper. They are also designed to accommodate substantially higher flow rates than would be used with enclosed flat plate or evacuated tube collectors. These collectors are often mounted on roofs at relatively low slope angle to optimize summertime solar gain. Pool-heating collectors are NOT suitable for domestic water-heating or space-heating applications.

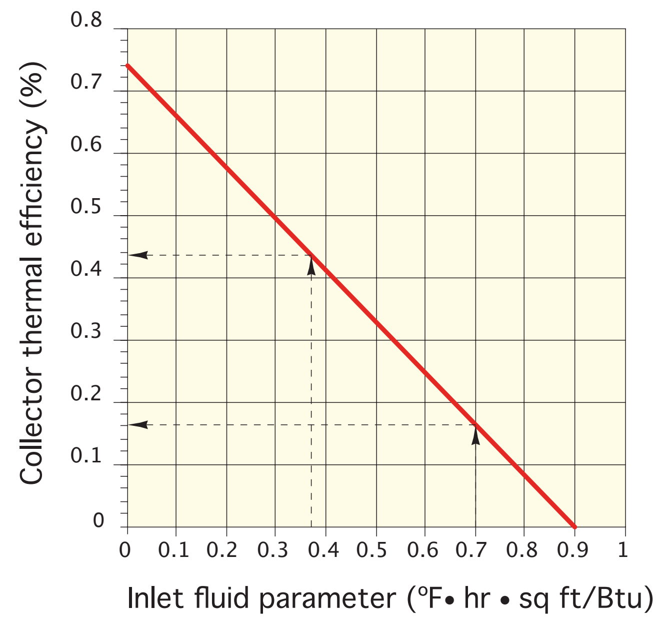
SOLAR COLLECTOR PERFORMANCE:

When designing active solar energy systems, it's important to be able to predict the thermal performance of solar collectors over a wide range of operating conditions.

One method of expressing the thermal performance of a collector is a numerical value for thermal efficiency, which is the ratio of the instantaneous heat output from the collector divided by the rate solar radiation strikes the panel. It is similar to the thermal efficiency of a boiler in that it states the desired output quantity (collected heat) as a percentage of the required input quantity (solar "fuel").

The thermal efficiency of a collector changes whenever the fluid inlet temperature, the ambient air temperature or the intensity of solar radiation striking it varies. To account for these factors, the thermal efficiency of a solar collector is typically expressed graphically, as shown in figure 15.

Figure 15



$$p = \frac{(T_i - T_a)}{I}$$

Here, the collector's thermal efficiency is plotted on the vertical axis as a function of a grouping of terms called the "inlet fluid parameter" on the horizontal axis.

$$p = \frac{(T_i - T_a)}{I}$$

Where:
Ti= inlet fluid temperature to the collector (ºF)
Ta = ambient air temperature surrounding the collector (ºF)
I = solar radiation intensity striking the collector (Btu/hr/ft^2)

The greater the value of the inlet fluid parameter, the more severe the conditions under which the collector operates, and the lower its thermal efficiency.

For example, assume water at 160ºF is supplied to a flat plate collector having the efficiency line shown in figure 15. At the same time, the outdoor air temperature surrounding the collector is 20ºF, and the solar radiation striking the collector is 200 Btu/hr/sq. ft. (see figure 4 for examples of solar radiation intensity). The inlet fluid parameter under these conditions is:

$$p = \frac{(T_i - T_a)}{I} = \frac{(160 - 20)}{200} = 0.7$$

Locating 0.7 on the horizontal axis of figure 15 and projecting up to the line and over to the vertical axis indicates the collector's thermal efficiency is 0.16 (e.g., 16%). Hence, under these operating conditions, only 16% of the solar energy striking the collector is converted into useful heat output. This is certainly not very high, especially when compared to the efficiency of hydronic heat sources such as boilers. The low efficiency is due to the unfavorable operating conditions (e.g., forcing the collector to operate with a relatively high inlet fluid temperature during cold outdoor conditions).

For comparison, assume the same collector operates in a system where it receives water at 95ºF under the same outdoor air temperature and solar radiation conditions. The inlet fluid parameter is now:

$$p = \frac{(T_i - T_a)}{I} = \frac{(95 - 20)}{200} = 0.375$$

Under these conditions, the collector's thermal efficiency is 0.43 or 43%. The significant drop in the inlet fluid temperature results in much higher thermal efficiency. This demonstrates that collector efficiency is extremely dependent on inlet fluid temperature. For the best performance, the inlet fluid temperature to any solar collector should be kept as low as possible.

The slope and vertical axis intercept of a solar collector's thermal efficiency line are established by testing. In the United States, the standard testing procedure is ASHRAE Standard 93-77 "Methods of Testing to Determine the Thermal Performance of Solar Collectors." The results of such testing are often published in technical literature for the solar collector. These performance indices are also used as inputs to software that simulates the thermal performance of solar energy systems. Examples of such simulations are given in later sections.

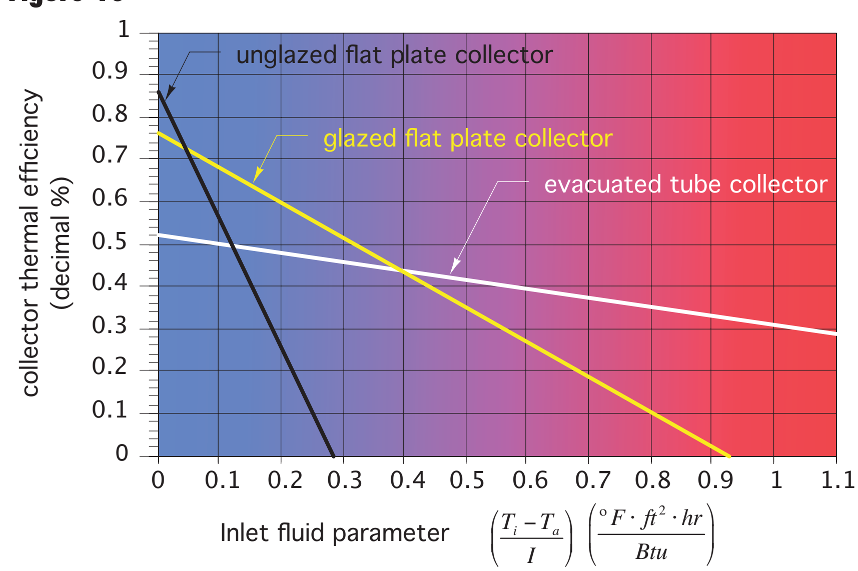
COMPARING SOLAR COLLECTOR PERFORMANCE:

Given the different construction of flat plate and evacuated tube solar collectors, it's reasonable to ask which type is better. There is no simple answer to this question. The collector with the greatest heat collection potential depends strongly on the specific application in which the collector will be used. Beyond thermal performance, the designer must also weigh factors such as differences in roof area requirements, maintenance requirements, ability to shed snow and the type of freeze protection options available for each type of collector.

From the standpoint of thermal performance only, the collector with the best performance depends on the temperature required by the load the system supplies. This is demonstrated by comparing the three collector efficiency lines shown in figure 16.

This graph is based on a sampling of performance ratings for different types of collectors as determined by the SRCC (Solar Rating and Certification Corporation). It shows that the collector with the highest thermal efficiency depends on the value of the inlet fluid parameter, which itself depends on collector inlet fluid temperature, outdoor air temperature and solar radiation intensity.

Figure 16



If the load is a swimming pool where water temperature is at or just above ambient air temperature, an unglazed flat plate collector will provide the highest thermal efficiency. This is the result of two factors: First, the incoming solar radiation is not attenuated by passing through a glazing; secondly, there is very little if any heat loss from an absorber plate operating close to ambient air temperature.

However, as the load temperature increases, an unglazed collector rapidly loses efficiency relative to a glazed/insulated flat plate collector. At even higher inlet fluid temperatures, an evacuated tube collector, with its very low heat loss characteristics, retains higher thermal efficiency than a glazed flat plate collector.

The only accurate way to compare seasonal performance of flat plate versus evacuated tube collectors is through computer simulation based on a specified load in a specified climate.

Other issues differentiate flat plate and evacuated tube collectors.

- Flat plate collectors typically have a higher ratio of absorber plate area per square foot of collector enclosure compared to evacuated tube collectors. This means evacuated tube collectors usually require more roof area to accommodate a given amount of absorber plate surface.
- Because of their manifold design, most current-generation evacuated tube collectors must operate with an antifreeze solution and are not suitable for other types of systems.
- Evacuated tube collectors tend to be more expensive than flat plate collectors on a dollar per square foot of absorber plate area basis.
- Flat plate collectors cannot produce water temperatures as high as those possible with evacuated tube collectors. This may or may not be an issue, depending on intended application.
- Some flat plate collectors can be architecturally integrated into roofs to minimize their visible profile.
- Flat plate collectors sloped at 40° or more shed snow sooner than evacuated tube collectors mounted at the same angle. The low heat loss of evacuated tube collectors increases the time needed to warm snow to the point where it will slide from the tubes.

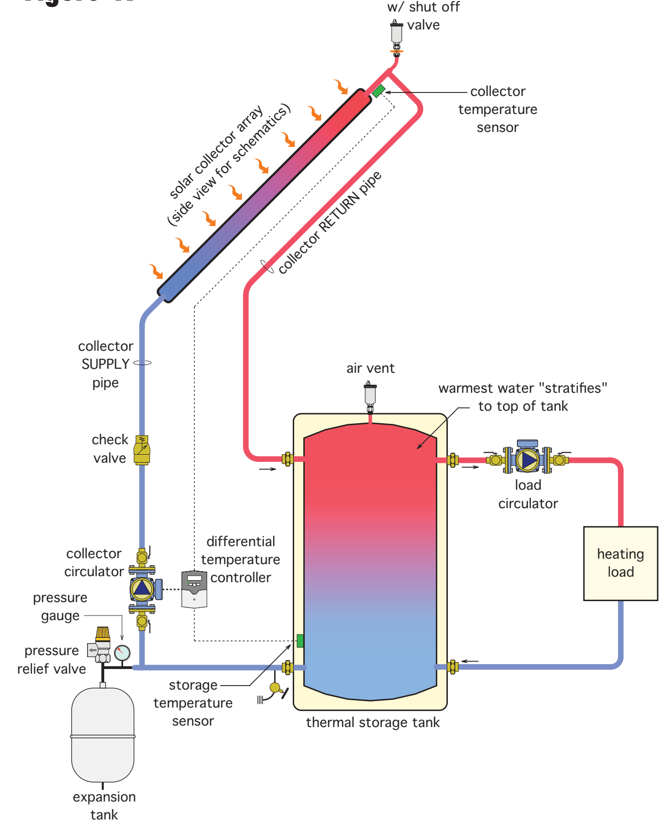
STAGNATION CONDITIONS:

There are times when solar collectors will likely be exposed to bright sun conditions without any fluid flow. Such a situation could result from a control or circulator malfunction, the storage tank reaching its high temperature limit or a power outage. Under such conditions, the collector is said to be “stagnating” and can reach internal temperatures of 350ºF or more. Such temperatures can cause failure of PEX or PEX-AL-PEX tubing and thus rule out its use between the collector array and mechanical room in most active solar systems. Prolonged stagnation can also cause a chemical breakdown of glycol-based antifreeze solutions. Some active solar energy systems are equipped with “heat dump” subsystems that limit temperatures under stagnation conditions.

TYPES OF ACTIVE SOLAR THERMAL SYSTEMS:

There are several ways to combine solar collectors with other hardware to build active solar energy systems. Designs differ with the intended use of collected heat as well as methods of freeze protection. This section discusses the basic system concepts used for domestic water heating and space heating. In some cases, both of these loads can be supplied from a single system.
A simplified schematic for an active solar thermal system is shown in figure 17.

Figure 17



The collector array (one or more collectors) is piped to a thermal storage tank. The collector circulator moves water from near the bottom of the storage tank up through the collector array and back to the tank. This circulator operates whenever the collector array is warmer than the storage tank. A check valve in the collector supply piping prevents reverse flow, which would otherwise occur when the collector temperature drops below the storage tank temperature. Another circulator is shown to move warm water from the top of the storage tank through the heating load as required.

Although simple in concept, this system as shown would seldom be suitable for a specific application. It doesn't contain any method of freeze protection, nor does it provide a way to supply heat to the load when the water in the storage tank is too cool to be used by that load. Both of these issues are critical to proper system operation and are addressed through the further refinement and detailing to be discussed.

CONTROLLING THE SOLAR COLLECTION PROCESS:

Most active solar energy collection systems are controlled by a differential temperature controller. This device monitors two temperature sensors. One is located within or very near the outlet of a solar collector. The other is mounted in contact with the metal wall of the storage tank, as shown in figure 17. The differential temperature controller constantly measures the temperature *difference* between these sensors. When the collector sensor temperature exceeds the storage tank temperature by a specific value (typically 3 to 10ºF) the controller turns on the collector circulator. When the collector temperature is very close to, equal to, or below the storage tank temperature, the controller turns off the collector circulator.

This control logic allows collection of solar energy whenever possible. On a given day, the differential temperature controller may turn the collector circulator on and off several times, depending on how the collector temperature is affected by cloud cover, wind or shading.

Some differential temperature controllers also operate the circulator at speeds proportional to the differential temperature between the collectors and storage tank. As this differential rises, the collector circulator speed increases, and vice versa. This technique reduces the electrical consumption of the circulator under partial sun conditions.

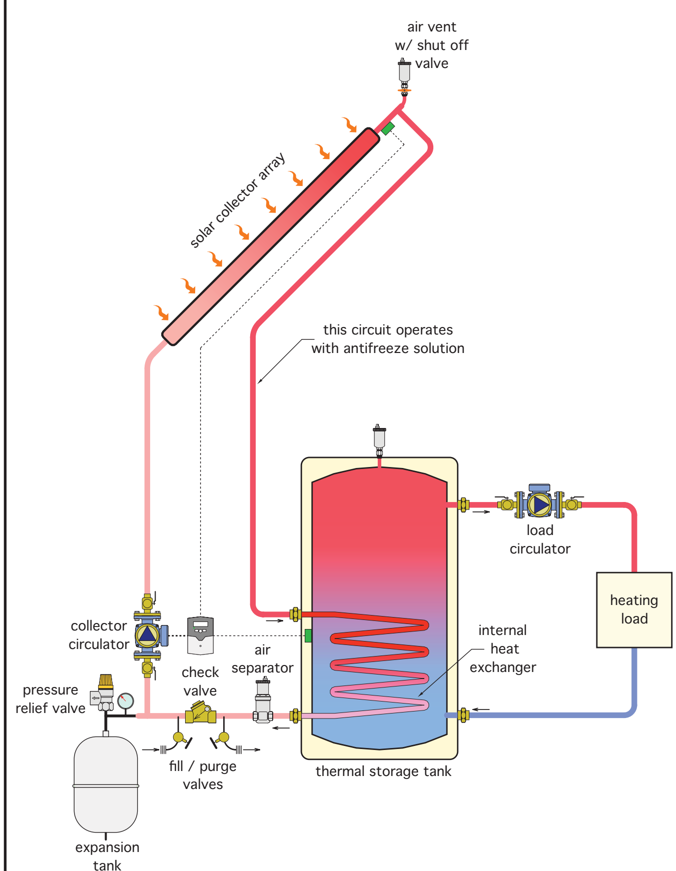
As with any temperature sensor, it is vital that the sensor housing remain in tight contact with the surface it is measuring. The portion of the sensor not in contact with the surface being measured should be protected by insulation to prevent readings from being affected by surrounding air.

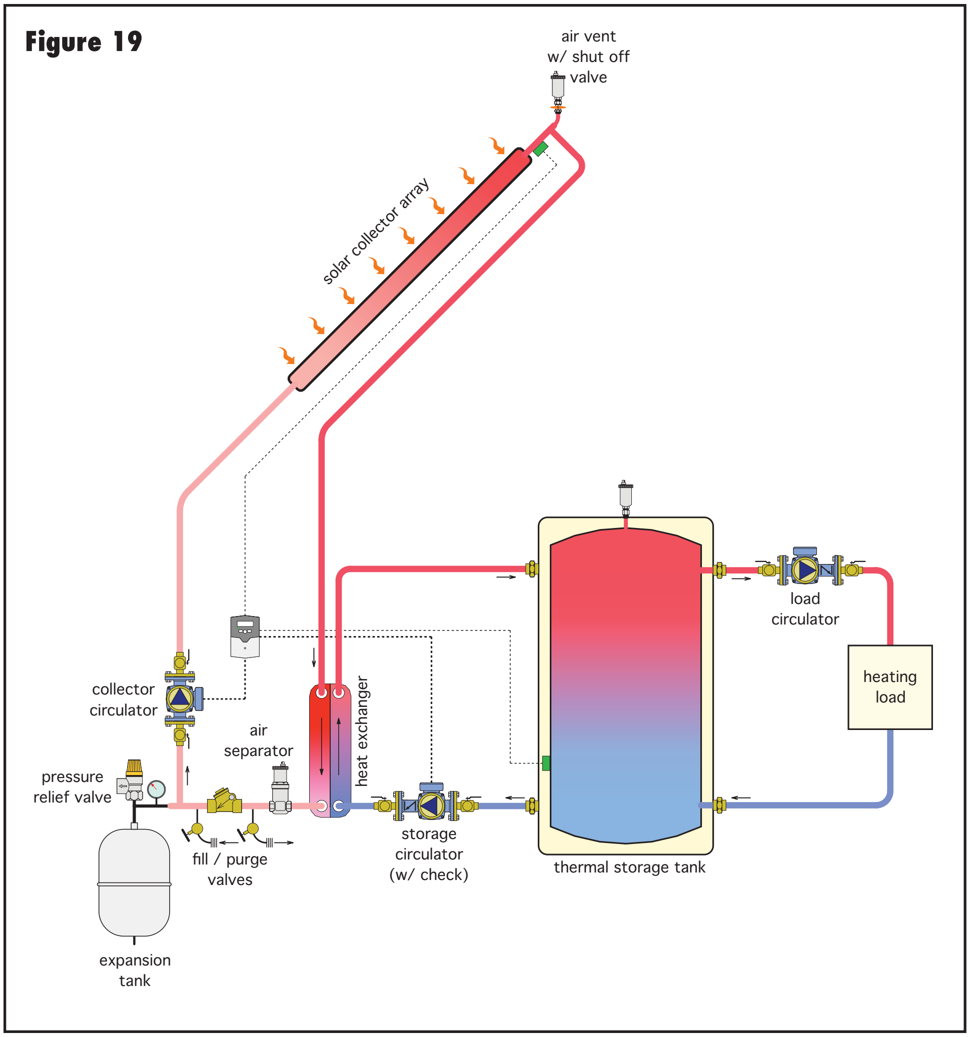
FREEZE PROTECTION METHODS:

Solar collectors containing water can be severely damage by a single night of sub-freezing temperatures. This can occur even in traditionally warm locations like Florida, Texas and Arizona. All active solar energy systems installed in the United States and Canada should employ some method of freeze protection.

Although manually draining the collector and any exposed piping when freezing conditions are imminent will prevent damage, this method relies on human intervention and is only suitable for climates where freezing conditions are extremely rare. All other locations should use a system designed for automatic and unattended freeze protection.

Figure 18





CLOSED-LOOP DRAINBACK SYSTEMS:

An alternative method of freeze protection is to drain all water from the collector array and exposed piping whenever the system is not collecting solar energy. This is called a drainback system. It relies on gravity along with properly pitched piping and collectors to quickly drain water whenever the collector circulator turns off. A schematic for a typical closed-loop drainback system is shown in figure 20.

In a drainback system, the collector circuit operates with water, and is initially filled to a predetermined level. That level is part way up the height of the drainback tank, as seen in figure 20. When the collector circulator is off, all piping above this water level, as well as the collector array, is filled with air, and thus not subject to damage when temperatures drop below freezing. All piping and components below the fill level are filled with water.

When the collector circulator turns on, water is pushed up the collector supply piping and into the collector array. This water pushes air ahead of it. Eventually the rising water reaches the top of the collector array and continues flowing down the return piping toward the drainback tank. Again, air is pushed ahead of the water or entrained with the flow, and eventually returned to the drainback tank. This process causes a slight drop in the water level within the drainback tank as water replaces air in the collectors and piping.

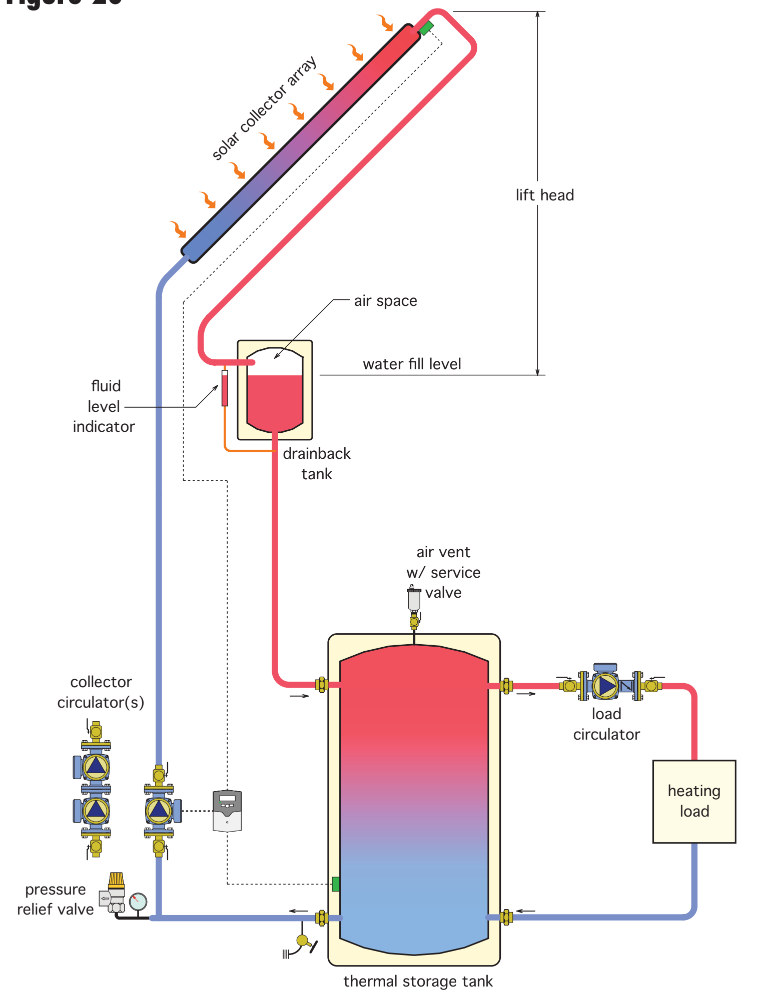
This operation continues as long as the collector circulator is running. As soon as this circulator shuts off, air from the top of the drainback tank rises up the collector return piping and into the collector array as water returns to the drainback tank. The majority of the water in the collector array usually siphons backward and returns downward into the storage tank. Since the storage tank is filled with water, the level within the drainback tank rises back to its original level.

One common method of freeze protection is to design the collector-to-storage circuit as a *closed loop* and operate it with a suitable antifreeze solution. This solution passes through the collector array and then through a heat exchanger that transfers the collected heat to water in the storage tank. The heat exchanger may be located within the storage tank as shown in figure 18, or outside the tank as shown in figure 19.

Systems with storage tanks having internal heat exchangers only require one collector circulator. Those with external heat exchangers require two circulators, and thus have slightly higher electrical power consumption.

Both types of heat exchangers should be generously sized to maximize system efficiency. The larger the heat exchanger, and the greater its effectiveness, the cooler the collector array can operate relative to the storage tank temperature. As previously discussed, the cooler the collector operates, the higher its efficiency.

Figure 20



It is critically important that any piping or other components located outside heated space are pitched a minimum of 1/4 inch per foot to allow efficient drainage. The collector array may also have to be pitched slightly to ensure complete drainage (verify with collector manufacturer).

The drainback system concept shown in figure 20 eliminates the need for heat exchangers and antifreeze. This allows the collectors to operate at the lowest possible temperature and thus optimizes their efficiency.

However, drainback systems typically require more electrical energy to maintain flow than do closed-loop antifreeze-based systems. This is a result of the "lift" requirement to push water up into the collector array and piping each time the circulator starts. In some systems, two circulators in series may be needed to provide the needed lift.

The collector return piping should be sized to ensure a flow velocity no lower than two feet per second. This ensures that air bubbles will be entrained and returned to the drainback tank when the collector circuit begins operation. It also allows a siphon effect to be established over the top of the collector array, which reduces the lift head present when the collector circulator first starts. When this is the case, it's common to operate the two series-connected collector circulators until a siphon is established over the top of the collector array and the return piping is completely filled with water. This process, which may take several minutes, eliminates the initial lift head and makes the circuit operate as a fluid-filled closed loop. Once the siphon is established, only one collector circulator is needed to maintain flow. The other (downstream) circulator can be turned off to reduce electrical consumption.

The collector circuit is a *closed loop*, as is the remainder of the hydronic system shown. The initial charge of water and air are thus sealed within the system and circulated over and over through the collectors and piping, as well as other parts of the system. The air within the drainback tank can be at a slight positive pressure relative to the atmosphere to ensure the remainder of the system operates under sufficient pressure. In some systems, the air space in the drainback tank can be sized to serve as the expansion volume for the system and thus eliminate the need for a traditional expansion tank.

No air vents are placed at the top of the collector array in a drainback system. No automatic make-up water system or air-separating device can remain active in this type of system past an initial filling condition. Doing so would eventually replace the air in the system with make-up water and thus "water log" the system. This would prevent drainage and eventually cause severe damage due to freezing.

WHICH METHOD OF FREEZE PROTECTION IS BEST?

Just like the choice between flat plate and evacuated tube collectors, there is no simple answer to this question. Listing the strength and limitations of each method can help steer the designer toward an appropriate choice for a given application.

***Strengths* of closed-loop antifreeze systems:**
- Pitched piping is not required
- Low wattage collector circulators can often be used
- No drainback tank is required

***Limitations* of closed-loop antifreeze systems:**

- Requires the added expense of heat exchangers and antifreeze, as well as additional pressure relief valve, expansion tank, fill/purge valve
- Forces collectors to operate slightly warmer than storage tank and thus at slightly reduced efficiency
- Antifreeze solutions are subject to chemical breakdown from prolonged stagnation conditions
- Chemical Ph of antifreeze solutions should be checked annually and fluid replacement is necessary when Ph of solution can no longer be maintained

***Strengths* of closed-loop drainback systems:**

- Slightly higher efficiency by operating collectors at lowest possible temperature
- Does not require antifreeze or other components associated with the use of antifreeze
- Drainback tank may serve as expansion tank for remainder of system

***Limitations* of closed-loop drainback systems:**

- Piping or collectors that are not properly pitched will result in costly hard freeze
- Higher pumping power required due to lift head
- Must ensure proper fluid level in system for drainback operation
- Requires drainback tank placed as high as possible within the system

As you can see, each approach has its advantages and disadvantages. The choice between the two tends to become easier in the context of specific applications.

ACTIVE SOLAR DOMESTIC WATER HEATING:

Some of the most economically viable active solar energy systems are those used for domestic water heating. They can be scaled for use in a single-family residence, or much larger for use in hotels, laundromats, carwashes or other commercial/industrial buildings with substantial domestic water-heating requirement. This section exams many of the options currently available.

SINGLE TANK SYSTEMS:

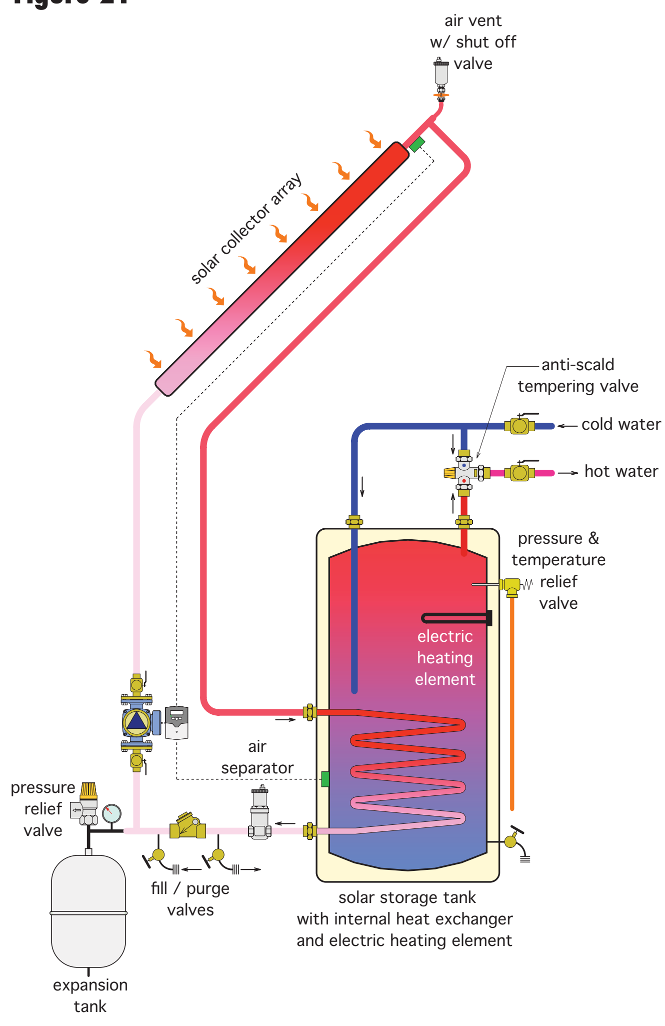
A schematic for a typical solar domestic water-heating system based on a single tank with internal heat exchanger is shown in figure 21.

This arrangement is called a single-tank system. An internal heat exchanger near the bottom of the tank provides solar heating (or preheating) of the domestic water in the tank. The upper portion of the tank is maintained at a set temperature by a thermostatically controlled electric heating element.

The warmest water stays near to the top of the tank due to its lower density. This helps preserve cooler water at the bottom of the tank to maximize the performance of the heat exchanger and keep collector temperatures as low as possible. Cold water entering the tank is directed near the bottom by the internal dip tube. Temperature stratification also ensures the hottest water is withdrawn from the top of the tank.

An anti-scald tempering valve rated to handle incoming water temperatures of at least 210ºF ensures that scalding hot water is not delivered to faucets or other fixtures. This is a crucially important component in any solar domestic water-heating system, which can easily produce scalding hot water during prolonged sunny weather, especially when demand is low.

Figure 21

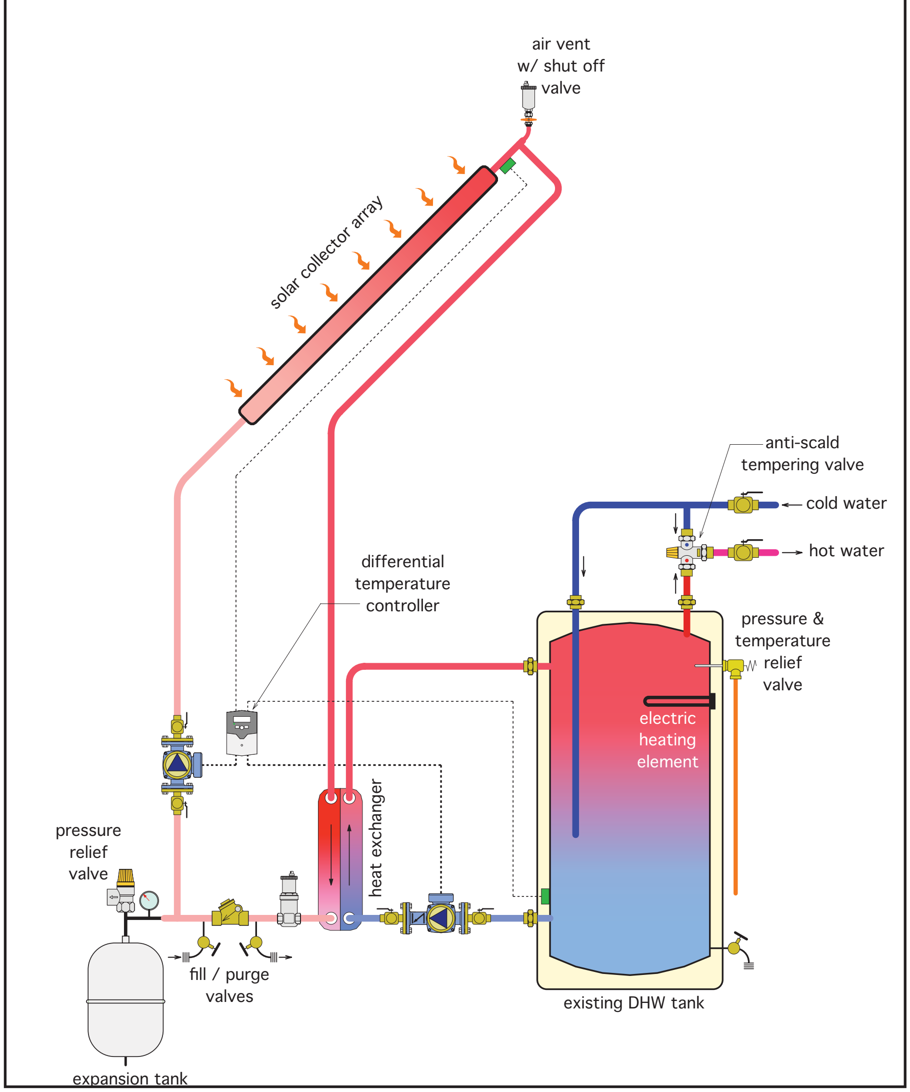


The solar collector circuit includes circulator, fill/purging valves, pressure relief valve, pressure gauge, expansion tank, air separator, check valves, and a high-point float-type air vent with shutoff valve. Many of these components provide the same function in the solar collection circuit as they would in a conventional hydronic system. As previously mentioned, the check valve prevents reverse flow when the collectors cool below the temperature of the storage tank. If such flow were allowed to occur, much of the heat within the tank would be dissipated through the collector array at night or under low sun conditions. The shutoff valve connecting the high-point float vent to the top of the collector array should be closed as soon as the collector loop has been deareated. This protects the vent mechanism against stagnation temperatures. The shutoff valve can be reopened if the collector loop is ever drained and refilled.

Another variation of a single-tank system is shown in figure 22. In this case, an external heat exchanger is used along with an additional circulator between that heat exchanger and the domestic water tank. This allows a properly sized existing domestic water storage tank to be retrofitted for solar heating. The storage tank should provide a minimum of 1 gallon of storage volume per square foot of collector area. Tanks that provide 1.5 to 2 gallons of storage per square foot of collector area will increase the solar energy collected on an annual basis. Be sure that any existing hot water tank retrofit in this manner is equipped with an anti-scald-rated thermostatic mixing valve to protect against possible high-temperature water produced during prolonged periods of sunny weather.

Single-tank systems have the advantage of a small footprint and reduced cost. However, they typically do not collect as much solar energy on an annual basis as do systems that separate the solar storage tank from the auxiliary heating means (in this case, the electric heating element).

Figure 22



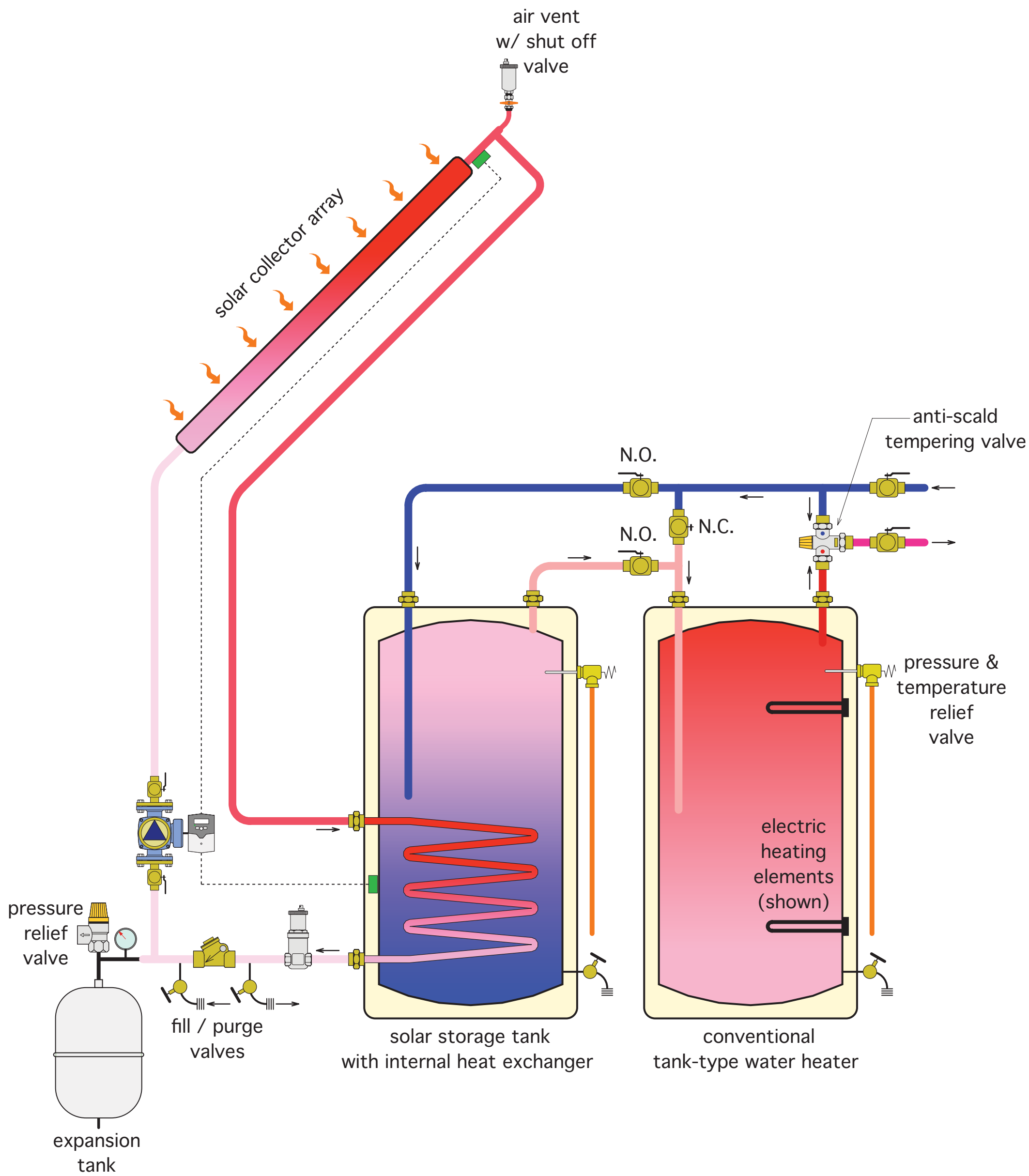
TWO-TANK SYSTEMS:

Another variation on the closed-loop antifreeze-based solar water-heating system is shown in figure 23. This is called a two-tank system, and it's typical for residential systems where a conventional water heater is already installed.

In a two-tank system, cold water first flows into the solar storage tank. During sunny weather this tank may provide all the heating necessary. However, during less favorable conditions the water may only be preheated. An example of the latter is 45ºF cold water warmed to 85ºF as it is drawn out of the solar storage tank. The preheated water then flows to the inlet port of a conventional tank-type water heater where heat from conventional fuel or electricity raises it to the required delivery temperature.

It's important to remember that, even when water leaving the solar storage tank has only been preheated, the process can represent a substantial reduction in conventional energy use. For example, water preheated from 50ºF to 90ºF represents about (40/70) or 57% of the energy input needed to

Figure 23



raise that water to a final temperature of 120ºF. It takes just as much heat to raise a gallon of water from 45 to 46ºF as it does to raise that water from 119 to 120ºF. Energy input at low temperatures is ideally suited to the solar portion of the system since low operating temperatures significantly improve collector efficiency.

Two-tank systems typically provide greater solar energy collection on an annual basis relative to single-tank systems. This is due to increased storage mass and the separation of conventional energy input from the solar storage tank. On the other hand, poorly insulated storage tanks can all but erase this potential performance advantage by leaking heat away from the water and into the surrounding air. In the absence of specific code requirements, all storage tanks should be insulated to a minimum of R12 (ºF•hr•ft^2/Btu), and all connecting piping should be insulated to at least R3 (ºF•hr•ft^2/Btu).

A set of three ball valves is shown on the piping between the two tanks in figure 23. These allow the solar storage tank to be completely isolated from the conventional tank, and the latter to act as the sole water-heating device should the solar system ever be shut down for service. Also note that both tanks are equipped with pressure and temperature relief valves.

BYPASS SYSTEMS:

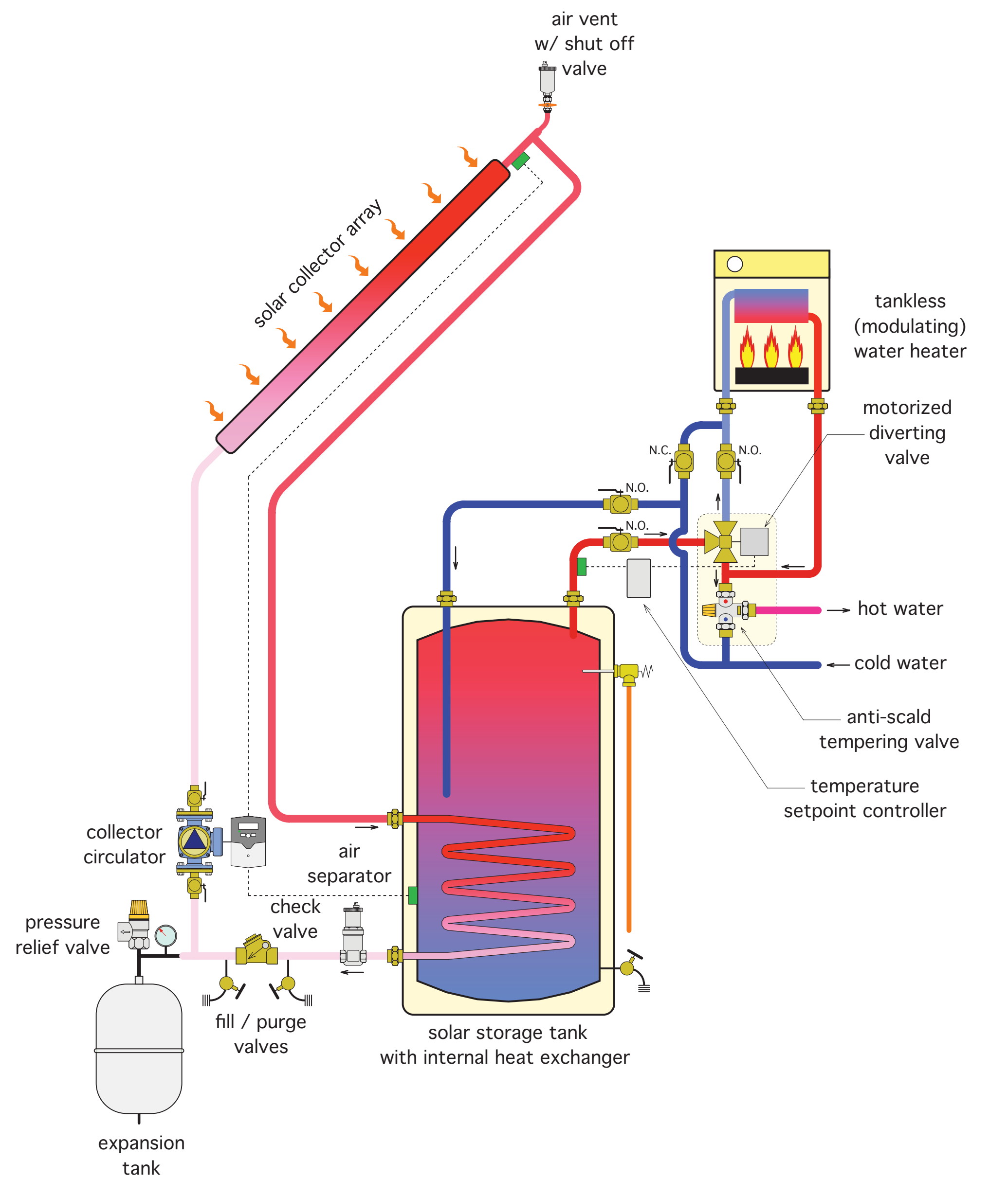
Still another method of constructing a solar water-heating system is shown in figure 24. This approach is especially relevant when modulating "tankless" water heaters are used for auxiliary domestic water heating.

In a bypass system, the temperature of the water leaving the solar storage tank is constantly measured. If the water is hot enough to go directly to the faucets, the motorized diverter valve routes it to the anti-scald tempering valve. If the water requires additional heating, the diverter valve routes it to the tankless water heater. From there it again passes to the anti-scald tempering valve before heading for the faucets.

Isolating ball valves are shown that allow the tankless water heater to function as the sole domestic water-heating device if the solar subsystem is turned off for servicing.

This approach has several unique benefits. First, it does not add heat derived from conventional energy to the solar storage tank, and thus allows the collectors to operate at the lowest possible temperature for high efficiency. Secondly, it does not have the exposed surface area of a second water storage tank. This, combined with the fact that heated water does not pass through the tankless heater unless it is operating, significantly reduces standby heat loss. Finally, this design significantly reduces the mechanical room "footprint" relative to a two-tank system.

Figure 24



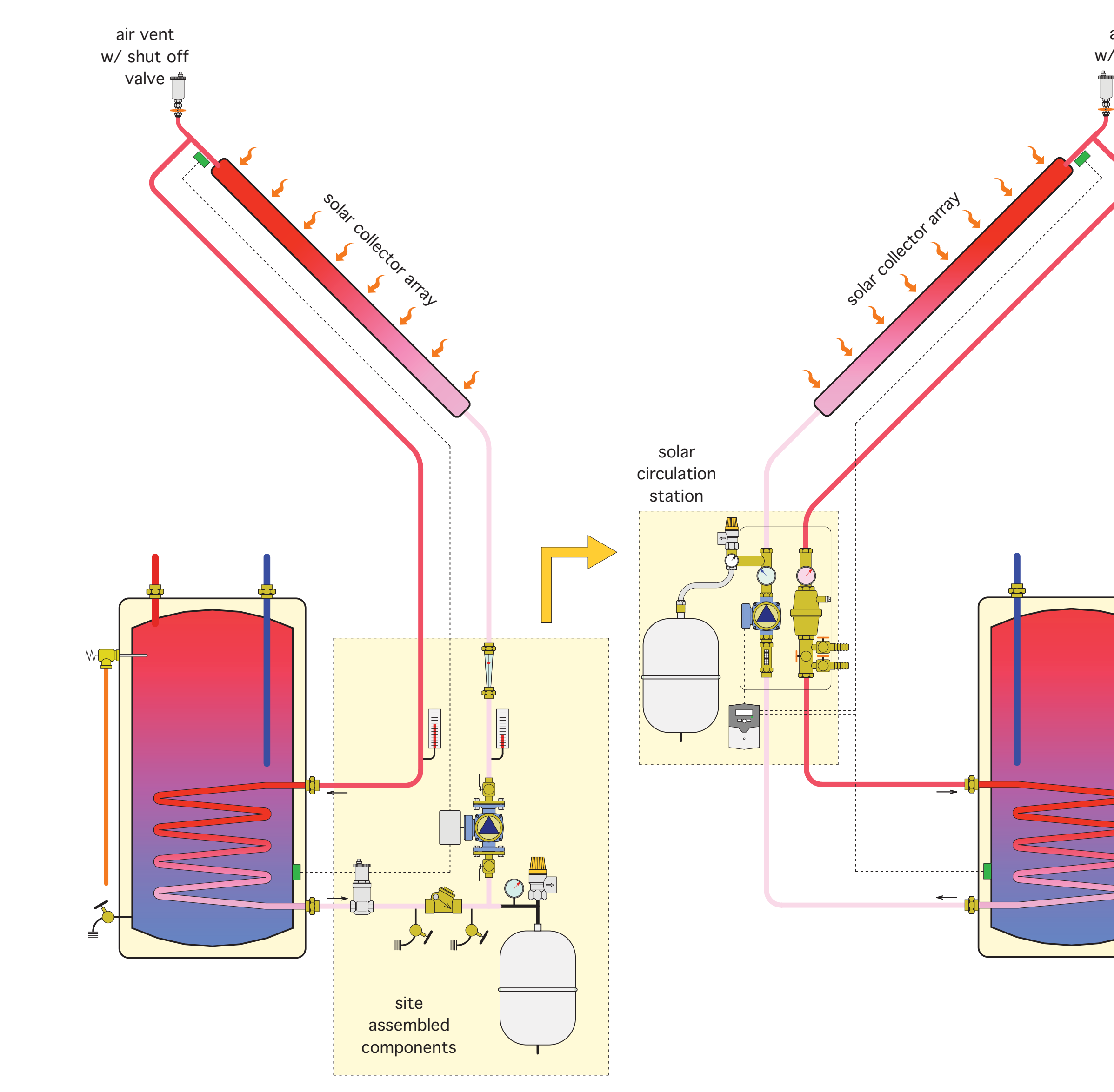


Figure 25

SOLAR CIRCULATION STATIONS:

Many solar domestic water-heating systems use the same or similar components within the solar collection circuit. To speed installation, some manufacturers offer preassembled “solar circulation stations” that combine the functionality of several independent components into a single unit. These stations speed installation and ensure all hardware is correctly sized and located. The concept of a solar circulation station is shown in figure 25.

ACTIVE SOLAR SPACE HEATING SYSTEMS:

Active solar space heating is possible, both as a singular application or in combination with other loads such as domestic water heating and pool heating. Carefully designed systems can provide years of reliable operation.

Given that solar availability is lowest when space-heating loads are highest, it’s unrealistic and uneconomical to attempt to supply 100% of a space-heating energy requirement through an active solar energy system. Active solar space-heating systems are almost always supplemented with an auxiliary heat source. In many cases, the transition from solar-derived heat to heat from conventional fuel is fully automatic and never noticed by the building occupants. In other systems, the auxiliary heat source may require manual start-up. An example of the latter is a wood stove.

There are three principles that need to be observed when designing solar space-heating systems.

Principle #1: Space-heating distribution systems that operate with low-temperature water will result in greater solar energy utilization.

Principle #2: Conventional energy sources (oil, gas and electricity) should only be "invoked" when instantaneously needed by the load. These fuels should not be converted to heat prior to being needed and stored in thermal form.

Principle #3: The collector array and all exposed piping components must be protected against freezing during non-operational periods.

SYSTEM CONFIGURATIONS:

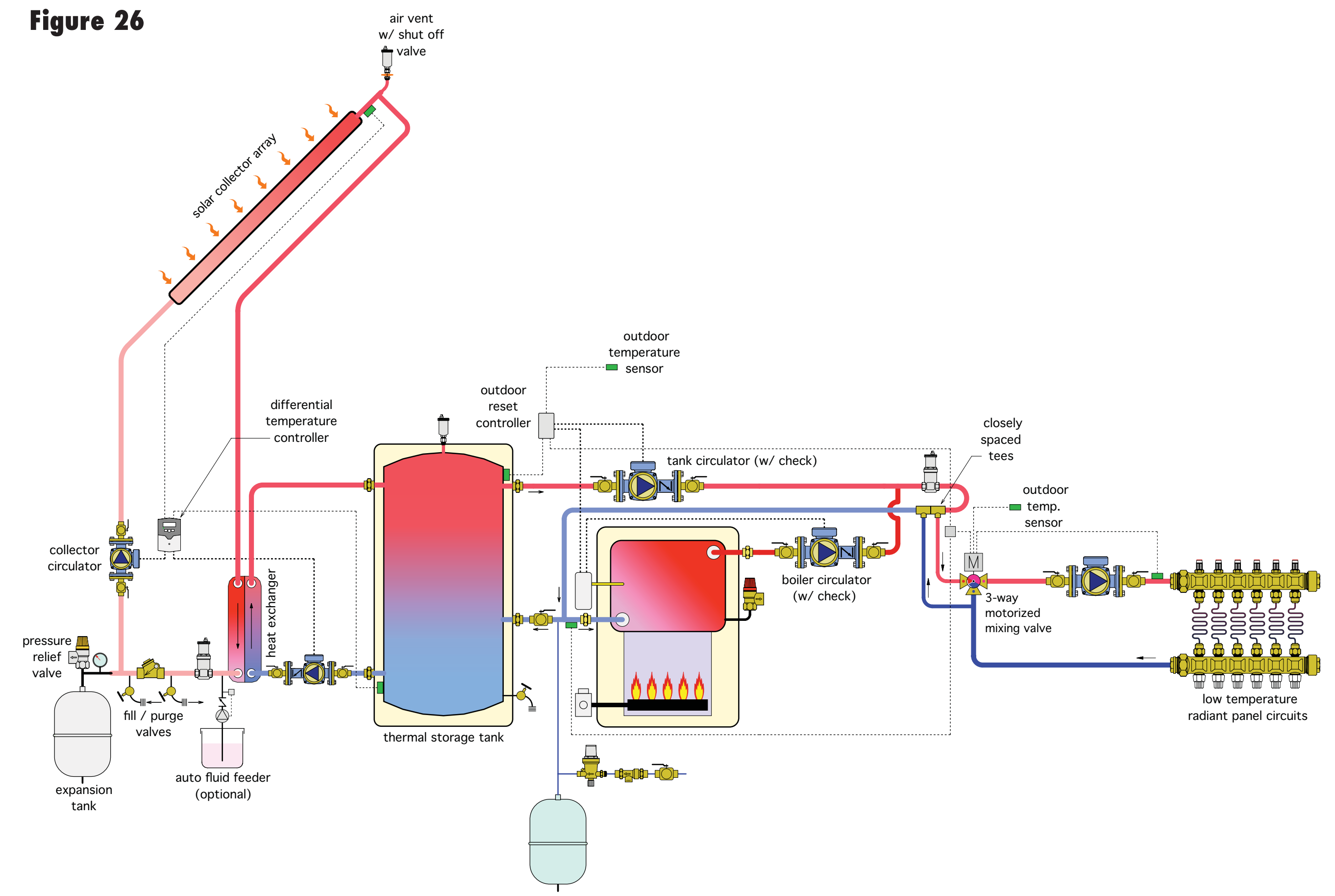
Hydronic-based solar subsystems can supply heat to either hydronic or forced-air space heating delivery systems.

Low-temperature hydronic floor heating is an ideal heat emitter to combine with active solar collectors. Parameters such as tube spacing, underside insulation and floor coverings should all be selected to allow the distribution system to operate at the lowest possible temperature.

An example of an antifreeze-based solar subsystem supplying a radiant panel distribution system in combination with a conventional gas-fired boiler is shown in figure 26.

The solar collection subsystem uses a stainless steel flat plate heat exchanger between the water in the storage tank and the antifreeze solution in the collector circuit. Because the latter is a closed loop, it's equipped with an expansion tank, pressure relief valve and fill/purging valves. The check valve prevents reverse flow of collector fluid when the collectors are cooler than the storage tank. A differential temperature controller constantly monitors the temperatures of the collectors and storage tank. Whenever the collector temperature exceeds the storage temperature by a set amount, the circulators on both sides of the heat exchanger are turned on. An optional automatic fluid feeder is shown. This device constantly monitors pressure in the collector circuit, and adds premixed glycol solution when necessary to compensate for minor drops in pressure. It is usually only needed in larger systems.

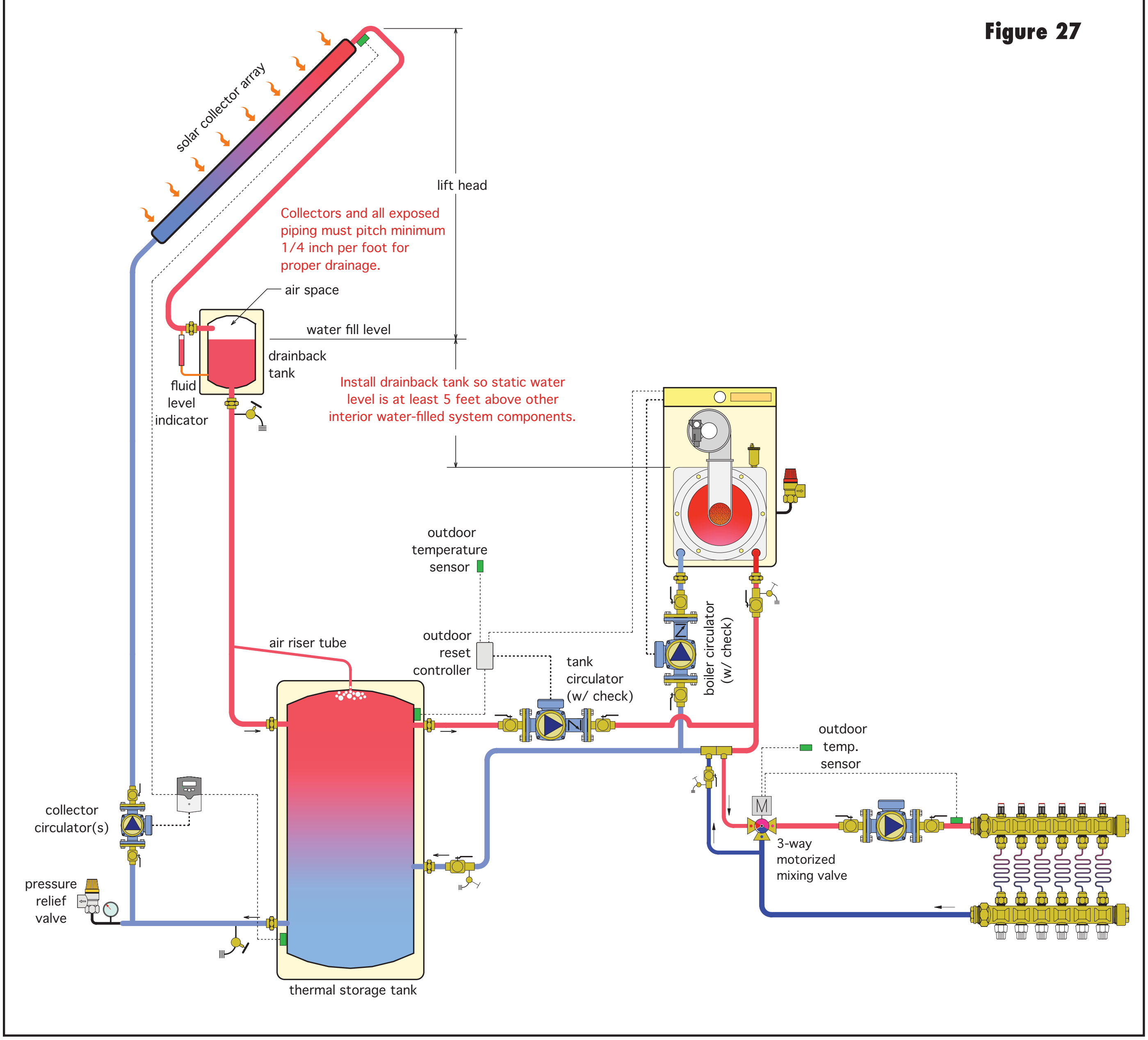
Figure 26



An outdoor reset controller monitors the temperature at the top of the solar storage tank and constantly calculates the water temperature needed at the supply side of the distribution system. Upon a call for space heating, this controller determines if the storage tank temperature is at or above the currently required supply temperature for the distribution system. If it is, the tank circulator is turned on and water from the tank passes through the air separator and on to the closely spaced tees. These tees are the interface to a 3-way motorized mixing valve that supplies the distribution system. This mixing valve ensures that water from the storage tank, which may be significantly hotter than required by the floor circuits, is not sent directly to them without being blended to the required temperature. The mixing valve also operates on outdoor reset control.

When there is a call for heat and the storage tank is below the minimum usable temperature of the distribution system, the boiler and boiler circulator are turned on. The storage tank circulator remains off. The 3-way motorized mixing valve allows the low-temperature distribution system to operate at the necessary temperature, while also protecting the conventional boiler from sustained flue gas condensation.

Figure 27



The mixing valve controller must “ignore” the boiler inlet temperature sensor when heat is supplied from the solar storage tank. This sensor is not required if a condensing boiler is used as the auxiliary heat source. However, the 3-way motorized mixing valve should still be installed to protect the distribution system against potentially high storage tank temperatures.

Notice that water heated by the boiler does not circulate through the storage tank. This allows residual heat (e.g., heat at temperatures below the minimum usable temperature of the distribution system) to slowly transfer from the tank into the surrounding space. The cooler the storage tank, the sooner the solar collection process can begin when sunshine returns. When the storage tank warms back above the minimal usable temperature of the distribution system, the storage tank automatically becomes the heat source for the system.

A similar system using drainback freeze protection and a modulating/condensing boiler is shown in figure 27.

The solar collection subsystem does not use a heat exchanger or antifreeze. This allows the collectors to operate at a slightly low water temperature and hence slightly higher efficiency relative to the antifreeze-based system.

The drainback tank should be placed as high as possible within the building to minimize lift head and minimize drainback volume. The fill level within this tank should be at least 5 feet higher than other water-filled components in the system to ensure a minimal static pressure at these components even with no positive air pressure in the drainback tank. Pressure within the system can be further increased by adding air to the drainback tank using a hand pump or compressor. Be sure system pressure is high enough to satisfy any pressure safety switches in the boiler.

The dimensions of the drainback tank must allow it to accept the drainback volume from the collector array and exposed piping. In many cases, the dimensions of this tank can also be selected so it can serve as the expansion volume for the system. This eliminates the need for a conventional expansion tank.

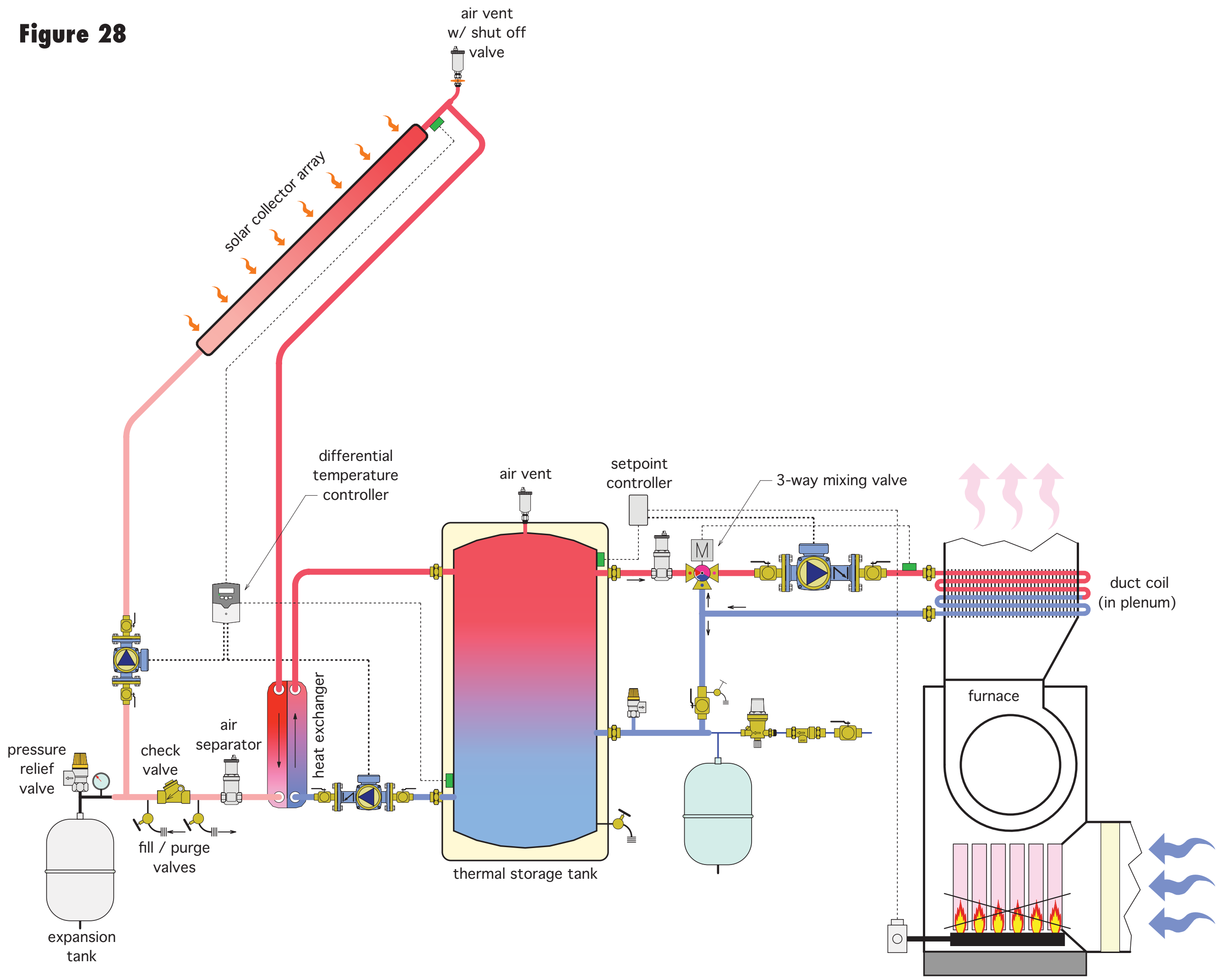
As is the case with any hydronic system, there will be dissolved air in the system water at start-up. As the water’s temperature rises, some of this air will come out of solution. The goal is to route this air to the upper portion of the system (collectors and drainback tank) rather than release it from the system. If the storage tank is capable of trapping air bubbles above the collector return piping connection, it should be equipped with a small diameter air riser line, as shown in figure 27. This allows air at the top of the tank to rise back to the drainback tank, while at the same time allowing the majority of water flow from the collector array to enter the storage tank horizontally to preserve thermal stratification.

Float-type air vents should be installed at intermediate high points in the system to allow escape of trapped air. An example is the vent at the top of the boiler in figure 27.

Drainback systems should NOT have automatic make-up water assemblies. Installing such an assembly in combination with an automatic venting device would eventually replace the air in the system with water. Although this is desirable in conventional hydronic systems, in this system it will lead to a “waterlogged” drainback tank that prevents the system from draining. A costly hard freeze is certain to follow.

The water level in the drainback system should be periodically monitored when the collector circulator is off. Small quantities of water may have to be added to the system, especially after initial start-up, to replace the volume of any air ejected through high point vents.

Figure 28



ACTIVE SOLAR SUPPLYING FORCED-AIR SPACE HEATING:

Although the majority of North American homes are heated by forced-air furnaces or heat pumps, they can still be adapted to hydronic-based solar heating. An example of such a system is shown in figure 28.

This system uses an antifreeze-based solar collection subsystem to heat the thermal storage tank. Upon a demand for heat, a setpoint temperature control determines if the water at the top of the storage tank is warm enough to supply space heating through the duct coil. If it is, a circulator moves tank water through the duct coil and operates the furnace blower. The 3-way mixing valve protects the coil against excessively hot water from the solar storage tank. When the water temperature in the storage tank can no longer provide acceptable comfort, the setpoint controller allows the furnace burner to operate, and the storage tank circulator is turned off.

This is a relatively simple system and easily adapted to most existing furnace or forced-air heat pump installations. The duct coil should be selected to operate at the lowest possible water temperature to maximize solar utilization while also providing acceptable comfort in the heated space.

COMBINED SOLAR SPACE & DOMESTIC WATER HEATING:

Many buildings with space-heating requirements also need domestic hot water. This is especially true of residential buildings. When a solar space-heating system is planned, it usually makes sense to extend the capabilities of that system to supply domestic water heating. In many situations, the auxiliary boiler that backs up the space-heating requirements can also supply auxiliary energy to the domestic water-heating load when necessary.

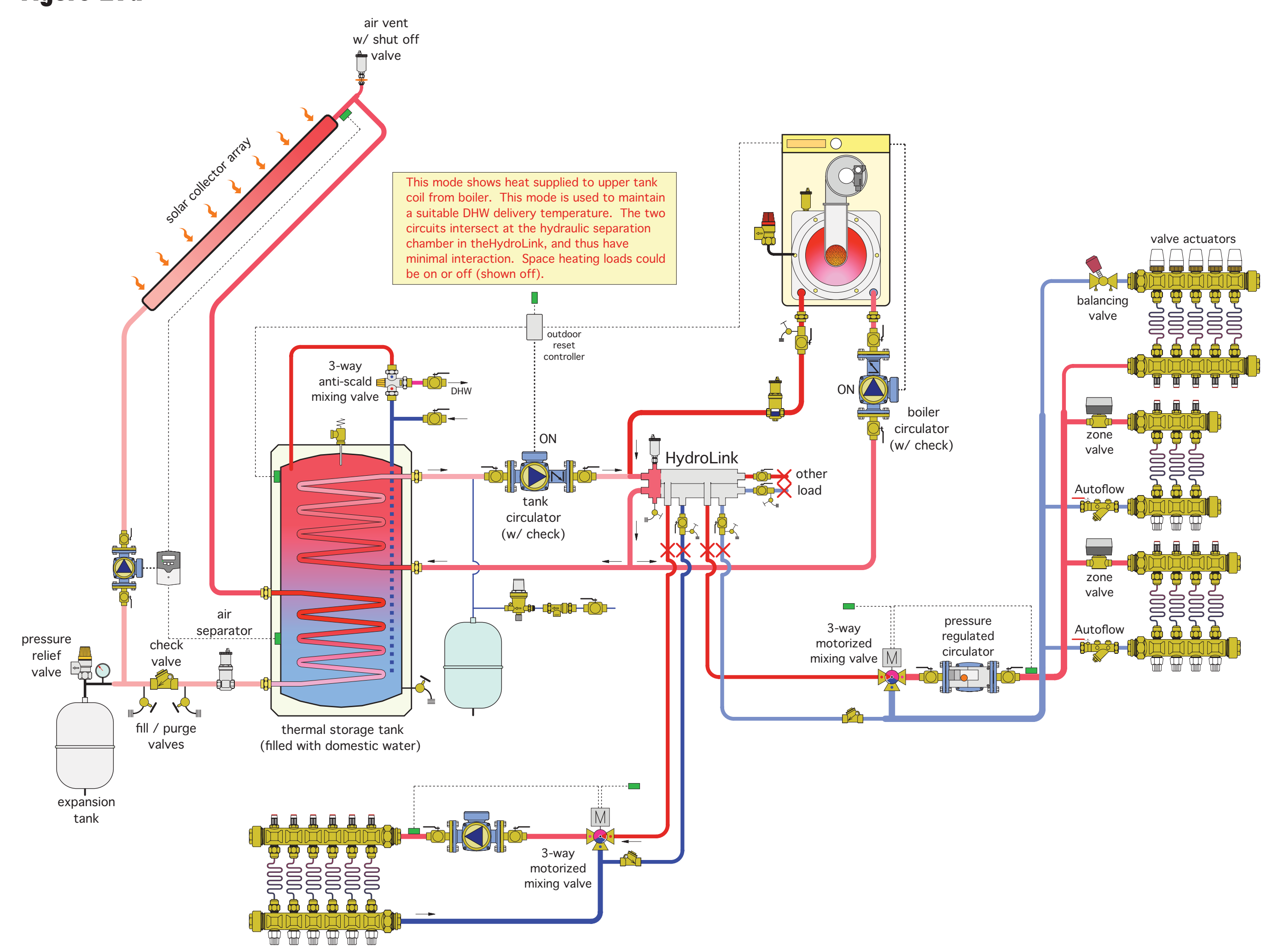
There are many hardware possibilities for combined solar space and domestic water heating. They vary on the solar collection side (i.e., antifreeze-based freeze protection versus drainback). They also vary based on available storage tank options, as well as the type of backup heat source used. This section discusses two state-of-the-art scenarios.

An example of one modern approach to solar space and domestic water heating is shown in figure 29a. A unique feature of this system is its dual coil storage tank, which contains domestic hot water and can be heated by the solar collection subsystem as well as the boiler.

Solar heat input is via a standard antifreeze-based closed-loop collector circuit. The lower coil heat exchanger is sized proportional to the collector array area. Since solar space heating typically requires more collector area than does solar domestic water heating, this coil may be substantially larger than the coils in tanks used only for domestic water heating.

The hottest domestic water is drawn from the top of the tank and passes through a 3-way anti-scald mixing valve to guard against excessively high water temperature at the faucets. The temperature at the top of the tank is constantly monitored. If it falls below a minimum

Figure 29a



setpoint, the boiler and its circulator are operated along with the tank circulator. Hot water from the boiler mixes with water returning from the upper coil, and the combined flow enters the hydraulic separation chamber in the HydroLink. This chamber minimizes interaction between the two circulators. A portion of the heated water then passes back to the upper tank coil to boost DHW temperature. The remaining portion of the heated water flows back to the boiler. This mode of operation is shown in figure 29a. Temperature stratification within the tank minimizes heating of the lower portion of the tank to ensure solar collection begins at the earliest opportunity.

The upper coil can also *extract* heat from the tank's water for use in space heating. With the boiler and its circulator off, the tank circulator moves hot water from the upper coil into the HydroLink. It is then distributed to the active space-heating circuits. Both space-heating circuits include motorized 3-way mixing valves to protect against high water temperatures reaching low-temperature heat emitters. These valves should be operated by outdoor reset controllers to ensure the distribution circuits operate at the lowest possible temperature commensurate with the building heating load. This mode of operation is shown in figure 29b. Controls would be configured to stop space heating from the upper coil in the event the domestic hot water temperature at the top of the tank dropped to a minimum acceptable value.

Another possible operating mode is for the boiler to supply space heating, as shown in figure 29c. In this mode, the tank circulator is off. The boiler operates on its own internal reset controller to produce a supply water temperature equal to or just slightly above the highest required space-heating supply temperature. The space-heating subsystems draw from the HydroLink as in a standard hydronic system.

Figure 29b

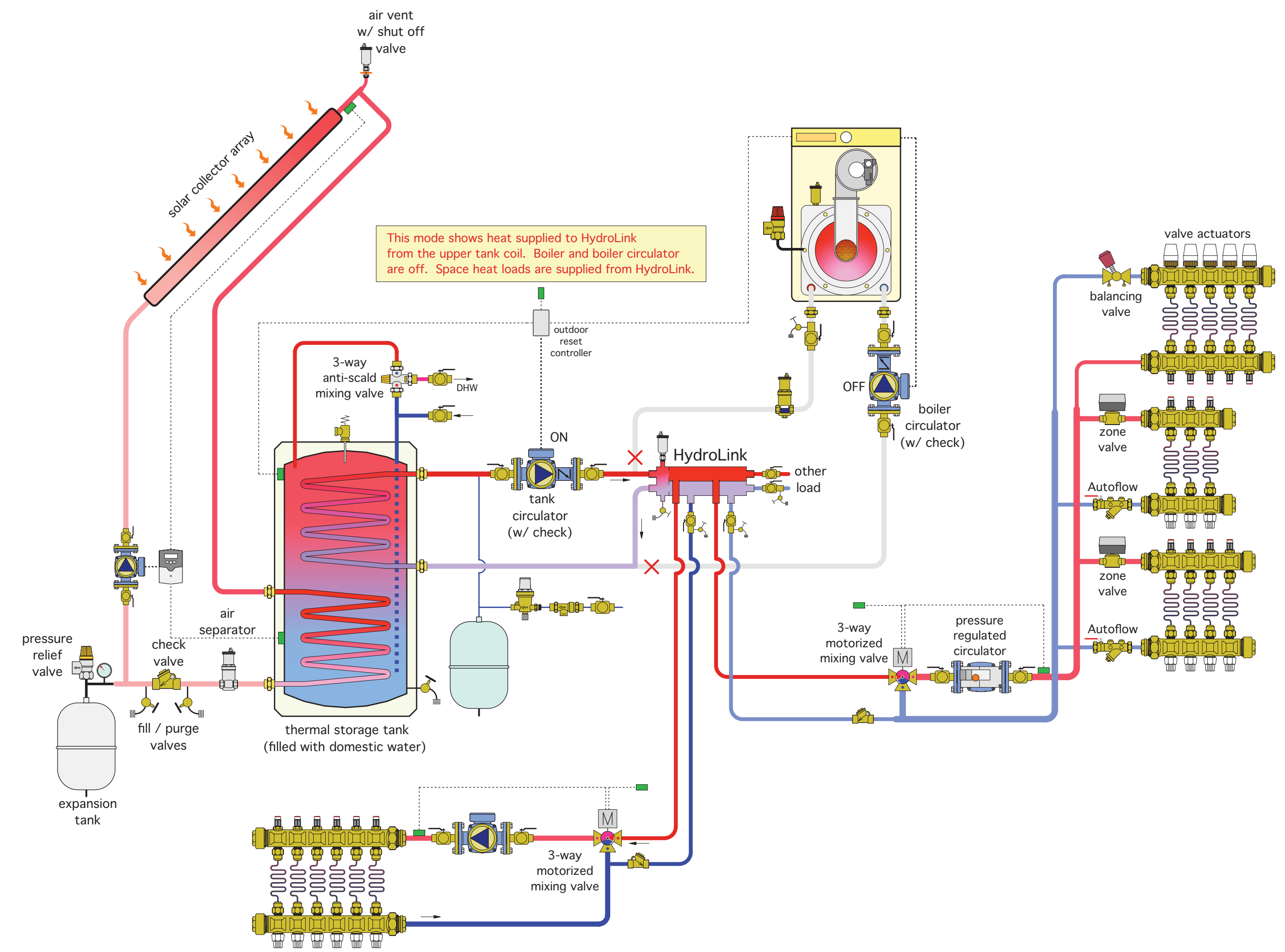


Figure 29c

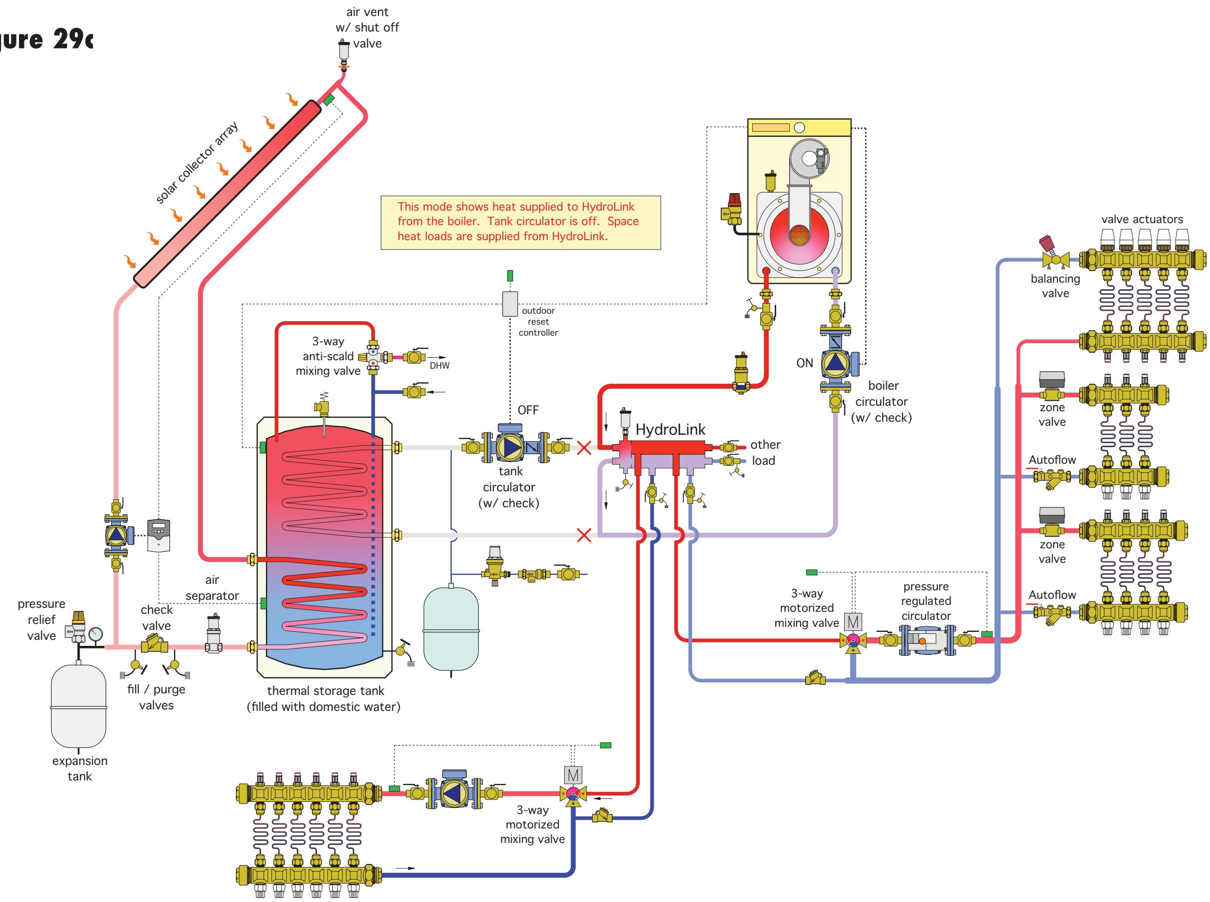
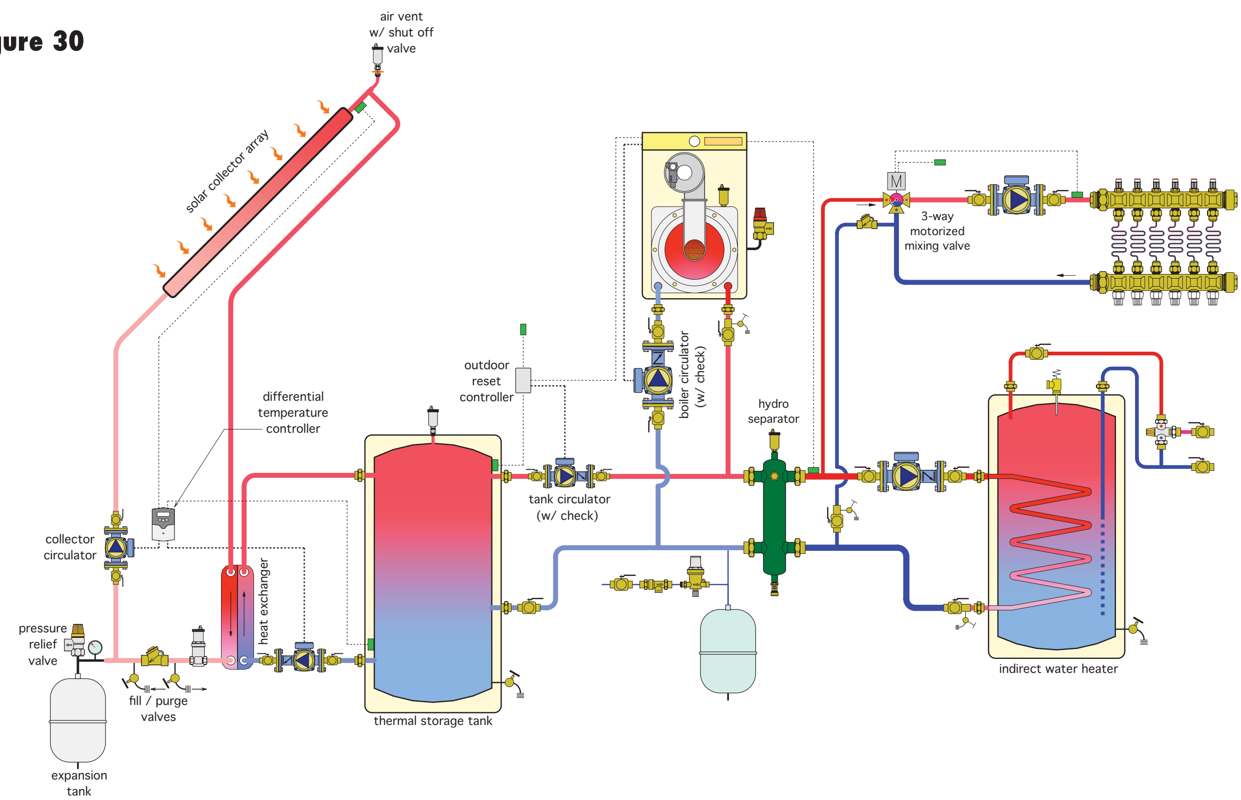


Figure 30



Another possible system design is shown in figure 30. This system uses a standard indirect water heater. A hydro separator hydraulically isolates the storage tank and boiler circulators from the circulators used for space heating and domestic water heating. It also serves as the central air and dirt separating device in the system.

Transition from solar-supplied heating to boiler-supplied heating is managed by the outdoor reset controller monitoring the solar storage tank temperature. This controller, or another controller, responds upon a call for domestic water heating to verify if the solar tank is sufficiently warm to supply the indirect water heater. If it is not, the boiler is fired to supply the indirect water heater. Space-heating circuits are temporarily turned off during this operation.

Again, the 3-way motorized mixing valve on the space-heating distribution system protects the low-temperature radiant panel circuits from potentially hot water supplied from the solar storage tank.

ACTIVE SOLAR SYSTEM INSTALLATION:

The performance and longevity of any active solar energy system depends greatly on proper siting of the collector array. Good performance obviously demands absolute minimal shading of the collectors. A proper assessment of every potential site is highly recommended, especially if there are any indications of shading.

Although it's possible to calculate the exact solar altitude and azimuth angles for any location on any day, using this information to assess the potential shading effects of nearby buildings, trees, hills or other objects is difficult. A much simpler approach is the use of a tool called a solar pathfinder, as shown in figure 31. This simple device is placed at the location where shading is to be evaluated. After being leveled and properly oriented using the internal compass, its clear hemispherical dome projects the reflections of nearby objects onto a special chart that indicates the approximate times and months when that location is shaded.

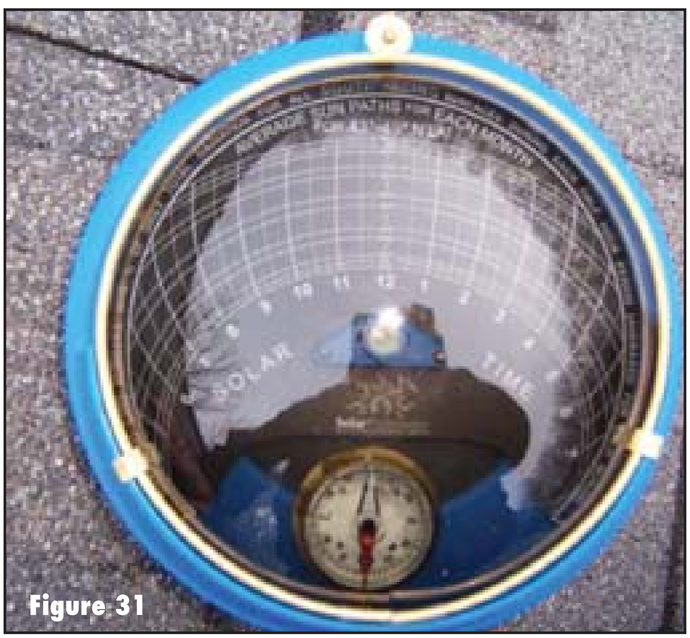


Figure 31

Image courtesy of SolarSkies, Inc.

Because solar intensity varies during the day, morning and late afternoon shading is not as critical as mid-day shading. As a rule, no portion of the collector array should be shaded between 9:00 AM and 3:00 PM (standard time).

The long-term reliability of an active solar system also depends on structurally sound collector mounting. Roof-, wall- and ground-mounted collector arrays are possible. Examples are shown in figure 32 and 33.


Figure 32

Photo courtesy of SolarSkies, Inc.


Figure 33

Photo courtesy of Hot Water Products, Inc.

Modern solar collectors are tested for survival under extreme wind conditions as well as the impact of large hailstones. Most are able to withstand such punishing weather conditions for decades. However, inadequate mounting hardware could fail and lead to major structural damage. All roof-mounted collectors should have bracket systems that connect directly to structural framing using stainless steel fasteners and proper sealants for roof penetrations. Ground-mounted collector supports should be designed by an engineer in accordance with local wind loading conditions. Verify that all mounting hardware complies with local code requirements.

All piping between the collector array and internal mechanical room should be properly insulated to a minimum of R3 (ºF•hr•ft^2/Btu), and protected against the weather where exposed. The piping must also be properly supported and pitched for drainage. In drainback systems, all piping exposed to freezing must be pitched to drain a minimum of 1/4 inch per foot of horizontal travel.

The equipment in the mechanical room should be neatly organized to minimize space requirements and provide easy access for service. When large storage tanks are planned into a system, provisions must be made for proper support as well as sufficient openings to get the tank into or out of the mechanical room. In some cases, multiple smaller tanks may be required to meet a specific storage requirement due to limited access.

COLLECTOR MOUNTING ANGLES:

In the Northern Hemisphere, the ideal collector array azimuth angle is 180º (e.g., the collector array faces directly polar south). This orientation maximizes total clear day solar radiation striking the array. However, existing building surfaces may not provide this orientation. Fortunately, the annual total solar energy captured by a collector array is not highly sensitive to the array's azimuth angle. Variations of 30º east or west of polar south typically only reduce annual solar energy collected by about 2.5%. The ideal slope angle of a solar collector depends on latitude as well as the intended function of the system.

For solar domestic water heating, the ideal slope angle is equal to local latitude. However, variations of +/- 10º on this angle will have minimal impact on the annual total solar energy collected. Thus, it often makes sense to mount collectors parallel to existing roofs where the slope of the roof is within +/-10º of local latitude, and forego the need for bracketing that would only make minor adjustments to the collector slope. In climates with snow, a minimum tilt angle of 40º is suggested to encourage rapid shedding of snow when the sun reappears.

In the case of solar space heating, somewhat steeper collector angles favor solar collection during late fall, winter, and early spring. Slope angles equal to local latitude plus 10º to 20º are appropriate for such systems. These relatively steep slopes actually reduce summertime solar collection and help prevent overheating from the larger collector arrays often used for space-heating applications. Even with this performance penalty, these larger arrays often provide a very high percentage of the domestic water-heating energy needed during warmer weather.

Figure 34 shows a collector array that supplies both space and domestic water heating. The collectors are sloped 60º in a location at 44º north latitude. In this project, the roof trusses were specially constructed to provide this collector slope while still mounting the collectors parallel to the roof surface.


Figure 34

ACTIVE SOLAR SYSTEM PERFORMANCE ESTIMATES:

Given the unlimited combinations of collector area, mounting angles, storage tank options, water temperature requirements and many other factors, it's essential to have a tool for evaluating the technical performance of proposed active solar energy systems. Given the extent of options and complex nature of solar energy availability, specialized software that simulates the performance of user-defined systems in a specific geographic location is the tool of choice. Several such software tools are currently available. Three of the most common are:

1. F-Chart: originally developed at the University of Wisconsin as a manual calculation procedure, the F-Chart method has been used for technical and economic analysis of active solar space- and domestic water-heating systems for over three decades. The current version of F-Chart software is available from www.fchart.com.

2. Tsol: Developed and primarily used in Europe, Tsol is simulation software for active solar thermal systems. It is available in both "express" and "professional" versions from http://www.valentin.de/.

3. RET Screen: Developed by Natural Resources Canada, RETScreen is powerful simulation software that can be used to study the technical and economic feasibility of active solar energy systems, as well as several other types of renewable energy technologies. This software is available as a free download from www.RETScreen.net.

The performance predictions presented in this section were derived using the latest version of F-chart software.

SOLAR HEATING FRACTION:

One way of expressing the thermal performance of an active solar energy system is by stating the percentage of the load met by solar energy on a month-by-month basis. These monthly totals can also be combined to yield the annual solar fraction. The solar heating fraction is sometimes expressed as a decimal percentage (e.g., 0.15 = 15%).

SIMULATED PERFORMANCE OF SOLAR DOMESTIC WATER-HEATING SYSTEMS:

The table in figure 35 lists the annual solar fraction for various domestic water-heating loads in three different U.S. cities (Boston, MA; Milwaukee, WI; and Las Vegas, NV). In all cases, the following system assumptions were made:

Flat plate collector efficiency line intercept (FRta) = 0.76
Flat plate collector efficiency line slope (FRul) = 0.825
Storage tank volume = collector area (ft^2) x 1.5 (gallon/ft^2)
Closed-loop antifreeze system with heat exchanger effectiveness = 0.50
Collector azimuth = 0º (e.g., collectors face directly south)
Collector slope = approximately equal to local latitude
Collector flow rate = 11 lb/hr/ft^2 (or 0.02 gpm/ft^2) of collector area
Setpoint temperature for domestic hot water = 120ºF
Cold water temperature = typical of location

Annual solar fractions are given for four daily hot water loads (left column) and three solar collector area/storage tank volume scenarios (top row).

[As would be expected, the larger collector arrays and correspondingly larger storage tanks yield higher solar heating fractions in all locations. In looking at these results, one might assume the best system is the one supplying the highest percentage of the load. From a pure energy conservation standpoint, this may be true. However, the economic viability of the system is a different matter. Systems that supply very high solar heating fractions may not provide returns on investment as high as systems supplying lesser amounts of the load. The only way to know for sure is through detailed economic analysis of competing system options. Most solar system simulation software can also perform an economic analysis of the system.

Figure 35

BOSTON	40 ft^2/60 gal.	80 ft^2/120 gal.	120 ft^2/180 gal.
40 gal/day	72%	91%	96%
60 gal/day	57%	85%	92%
80 gal/day	48%	77%	89%
100 gal/day	41%	69%	84%

MILWAUKEE	40 ft^2/60 gal.	80 ft^2/120 gal.	120 ft^2/180 gal.
40 gal/day	67%	88%	94%
60 gal/day	54%	82%	90%
80 gal/day	45%	74%	86%
100 gal/day	38%	65%	81%

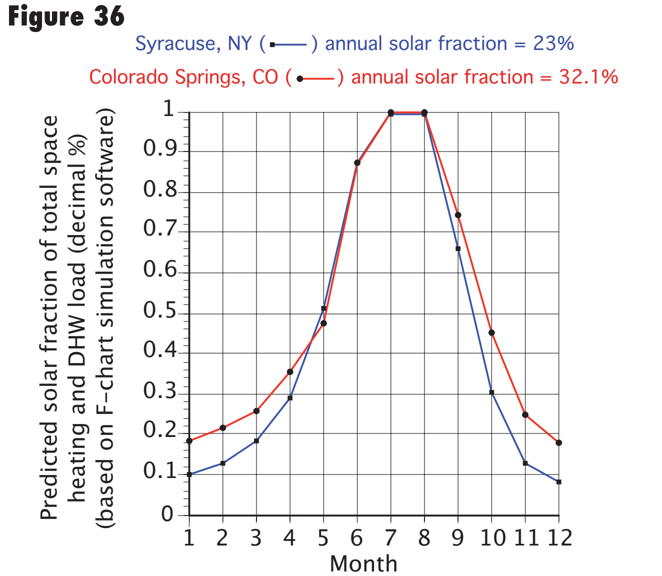
LAS VEGAS	40 ft^2/60 gal.	80 ft^2/120 gal.	120 ft^2/180 gal.
40 gal/day	94%	99%	100%
60 gal/day	88%	98%	100%
80 gal/day	77%	96%	99%
100 gal/day	69%	94%	98%

SIMULATED PERFORMANCE OF COMBINED SOLAR SPACE AND DOMESTIC WATER-HEATING SYSTEMS:

Figure 36 shows the monthly solar heating fraction for the energy required to heat a house with a design heat loss of 50,000 Btu/hr located in either Syracuse, NY, or Colorado Springs, CO. In each case, the system also supplies heat to a 60 gallons per day domestic hot water load having a setpoint temperature of 120ºF.

The collector array for the system is that shown in figure 34. The six flat plate collectors have a total gross area of 112 square feet and face directly south at a slope of 60º. The storage tank has a volume of 300 gallons and is equipped with an upper coil heat exchanger for domestic water heating. Space heating is supplied through low-temperature heated floors.

Figure 36



Not surprisingly, the monthly solar heating fractions are rather low in winter given the relatively cold climates. However, it's clear the system in Colorado Springs does significantly better at supplying winter heat compared to the same system in the much cloudier Syracuse, NY, location.

In both locations, solar fractions rise significantly during spring and fall. This results from increased solar energy availability as well as reduced heating load. As the space-heating load goes away during summer, both systems are able to supply very high percentages of the domestic water-heating load. During July and August, each system is estimated to supply 99-100% of the domestic water-heating load. Keep in mind that the collector slope of 60º favors winter sun angles. However, the relatively large collector area more than compensates for the losses due to the steep collector slope.

SOLAR PRODUCT CERTIFICATIONS:

Maintaining the quality of solar energy products and system installations is vital to the long-term success of the solar energy industry. To this end, the Solar Rating and Certification Corporation (SRCC) was formed in 1980 as a non-profit organization to provide independent testing, rating and certification of active solar collectors and solar domestic water-heating systems.

The SRCC has developed and maintains two standards for testing and rating of solar hardware:

- Standard OG-100 "Operating Guidelines for Certifying Solar Collectors"

- Standard OG –300 "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems"

These guidelines are widely accepted across the United States as the basis for qualifying collectors and domestic water-heating systems for state and national tax credits, as well as for other organizations offering financial incentives for solar system installation.

Standard OG-100 requires that collectors undergo stringent testing for both thermal performance and durability. Collectors are tested for thermal output under a range of solar intensity and ambient temperature conditions. Their ability to withstand stagnation, severe weather and thermal stock are also tested.

Standard OG-300 combines the physical testing of collectors with a quality assurance review of all major components in a solar water-heating system proposed for sale by a manufacturer. The standard also provides simulated performance estimates for that system in specific geographic locations.

Additional information on the SRCC can be obtained from their Web site, www.solar-rating.org.

SUMMARY:

We've discussed the fundamentals of active solar energy systems. As with hydronic heating, there are many specialized sub-topics within this area of technology. Future releases of idronics will address these subjects in more detail.

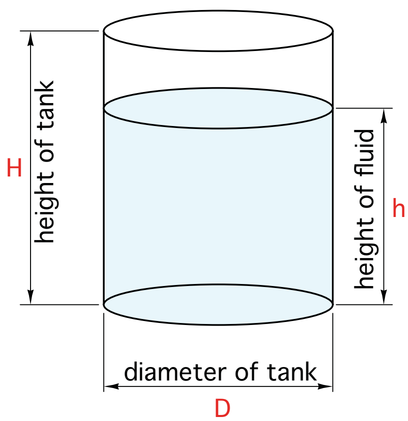
The use of solar energy in North America will increase with each passing year. Rapid increases in the cost of conventional fuel will accelerate the pace of this expansion. Knowing how to size and configure active solar heating systems is an important skill for hydronic heating professionals that expect to serve the growing demand for active solar space-heating and domestic water-heating systems.

APPENDIX

APPENDIX 1:
Volume and surface area reference information:

This appendix provides formulas and data for calculating the volume and surface areas of cylindrical tanks as well as the volume of tubing used in solar / hydronic systems.

Tank volume formula:
Formula 1 can be used to calculate the volume of a cylindrical storage tank of known diameter and height:



Formula 1:

$$V_{tank} = \frac{\pi\left(D^2\right)H}{924}$$

Where:
V_{tank} = volume of tank (gallons)
D = diameter of tank (inches)
H = height of tank (inches)

Formula 2 can be used to calculate the volume of liquid of known height (h) with a vertically-oriented cylindrical storage tank of known diameter and height:

Formula 2:

$$V_{fluid} = \frac{\pi\left(D^2\right)h}{924}$$

Where:
V_{fluid} = volume of fluid in tank (gallons)
D = diameter of tank (inches)
h = height of fluid in tank (inches)

Tank surface area formula:
Formula 3 can be used to calculate the total surface area of a cylindrical tank of known diameter and height:

Formula 3:

$$A_{surface} = \frac{\pi}{144}\left[\frac{D^2}{2} + DH\right]$$

Where:
$A_{surface}$ = total surface area of tank (square feet)
D = diameter of tank (inches)
H = height of tank (inches)

Pipe volume data:
The data in table 1 can be used to calculate the volume of tubing in solar energy systems as well as other types of hydronic systems.

Tube type/size	Gallons/foot
3/8″ type M copper:	0.008272
1/2″ type M copper:	0.0132
3/4″ type M copper:	0.0269
1″ type M copper:	0.0454
1.25″ type M copper:	0.068
1.5″ type M copper:	0.095
2″ type M copper:	0.165
2.5″ type M copper:	0.2543
3″ type M copper:	0.3630
3/8″ PEX	0.005294
1/2″ PEX	0.009609
5/8″ PEX	0.01393
3/4″ PEX	0.01894
1″ PEX	0.03128
1.25″ PEX	0.04668
1.5″ PEX	0.06516
2″ PEX	0.1116
3/8″ PEX-AL-PEX	0.00489
1/2″ PEX-AL-PEX	0.01038
5/8″ PEX-AL-PEX	0.01658
3/4″ PEX-AL-PEX	0.02654
1″ PEX-AL-PEX	0.04351

Table 1

APPENDIX 2:
Expansion Tank Sizing for Solar Collection Circuits:

During its service life, almost every closed-loop solar collection system will experience stagnation conditions, where bright sunshine strikes the collectors without flow through the absorber plates. Under such conditions, the fluid within the collectors can change to vapor. In addition, the fluid within the piping to and from the collector array could be filled with very hot fluid.

To prevent the relief valve from opening under these conditions, the expansion tank must absorb the liquid volume expansion plus the fluid displacement volume caused by vapor formation in the collector array. The following procedure determines the minimum volume of a diaphragm-type expansion tank volume to accommodate this situation.

Step 1: Calculate the potential expansion volume of the entire collector circuit using formula 5a.

Formula 5a

$$V_a = 1.1\left(V_c + V_p\right)e + V_c$$

Where:
V_a = expansion volume to be accommodated (gallons).
V_c = total volume of collector array (gallons)
V_p = total volume of collector circuit other than collector array (gallons)
e = coefficient of expansion of collector circuit fluid (e = 0.045 for water, or e=0.07 for glycol)
1.1 = safety factor of 10% to allow for system volume estimates

The volume of the collectors is usually listed in the manufacturer's specifications, as is the volume of the heat exchanger. The volume of the piping can be estimated using data from table 1 in appendix 1.

Step 2: Calculate the static pressure at the location of the pressure relief valve. This is the pressure caused by the weight of fluid in the collector circuit above the pressure relief valve location. It can be calculated using formula 5b.

Formula 5b:

$$P_i = H\left(0.454\right) + 5$$

Where:
P_i = initial pressure at the relief valve location (psi)
H = height of collector circuit above location of pressure relief valve (feet)
0.454 = constant based on the density of 50% propylene glycol
5 = allowance for 5 psi gauge pressure at top of collector circuit

Note: The air chamber in the expansion tank must be pressurized to the pressure calculated using Formula 5b before fluid is added to the collector circuit.

Step 3: Calculate the minimum required expansion tank volume using formula 5c.

Formula 5c

$$V_T = V_a\left(\frac{P_f + 14.7}{P_f - P_i}\right)$$

Where:
V_T = minimum required expansion tank volume (gallons)
V_a = expansion volume to be accommodated (from step 1) (gallons)
P_i = initial pressure at the relief valve location (from step 2) (psig)
P_f = maximum allowed pressure at the relief valve location (psig). Recommended value is pressure relief valve rating minus 5 psi

Example: Determine the minimum expansion tank volume for the following system:

- 4 collectors, each having a volume of 1.5 gallons
- Total of 120 feet of 1-inch copper tubing between heat exchanger and collector array
- Heat exchanger volume = 2.5 gallons
- Height of top of collector array above relief valve location = 25 feet
- Pressure relief valve rating = 60 psi
- Collector circuit fluid = 50% solution of propylene glycol

Solution:
— Total collector array volume:
4 x 1.5 = 6 gallons

— Total piping + heat exchanger volume:
120 ft x (0.0454 gallon/ft) + 2.5 = 7.95 gallons

Step 1:

$$V_a = 1.1\ (V_c + V_p)\, e + V_c\ \ = 1.1\ (6 + 7.95)\, 0.07 + 6\ \ = 7.67\ gallons$$

Step 2:

$$P_i = 25(0.454) + 5 = 16.35\, psi$$

— Pressure at relief valve under stagnation (relief valve rating – 5 psi):
Pf = 60 – 5 = 55 psi

Step 3:

$$V_T = V_a \left(\frac{P_f + 1}{P_f - P_i} \right) = 7.67 \left(\frac{55 + 14.7}{55 - 16.35} \right) = 13.8\, gallons$$

This procedure is "conservative" in several ways:

- It assumes that all collector circuit piping contains fluid at the maximum system temperature.
- It allows a 5 psi margin between the rated opening pressure of the relief valve and the pressure allowed to occur at the relief valve during stagnation.
- It assumes that all the fluid in the collector array has changed to vapor under stagnation conditions.
- It adds 10% to the estimated system piping volume.

A conservatively sized expansion tank is good "insurance" against the system requiring servicing following a stagnation condition.

In cases where the minimum required expansion tank volume exceeds the volume of available tanks, it is acceptable to use multiple tanks connected in parallel. Be sure the air side pressure in each tank is set to the calculated pressure (Pi) prior to filling the collector circuit.

APPENDIX 3:
Domestic water-heating load estimating:

Formula 5 can be used to estimate the energy required for heating domestic water. A typical North American family uses about 20 gallons of hot water per day per person.
Formula 5:

$$E_{DHW} = 8.33(g)(T_h - T_c)$$

Where:
E_{DHW} = Daily energy required for domestic hot water (Btu)
g = day requirement of domestic hot water required (gallons)
T_h = setpoint temperature of hot water heater (ºF)
T_c = entering cold water temperature (ºF)

APPENDIX 4:
Unit Conversion Factors:

Temperature

$$°F = (°C \times 1.8) + 32$$

Temperature difference (ΔT):

$$1^\circ\, Ra = 0.555555^\circ\, K$$
$$1^\circ\, F = 0.555555^\circ C$$

Heat:

$$1 Btu = 0.000293\, kwhr = 1054.8\, joule = 1.0548\, kilojoule$$

Power:

$$1 \frac{Btu}{hr} = 0.2929974\, w = 0.0002929974\, kw$$

Pressure:

$$1 psi = 0.068046\, bar = 6894.76\, Pa = 6.89476\, KPa$$

Volume:

$$1 gallon = 3.78533\, liter = 0.0037854\, meter^3$$

Flow rate:

$$1 gpm = 0.227126 \frac{meter^3}{hour} = 0.0630888 \frac{liter}{second}$$

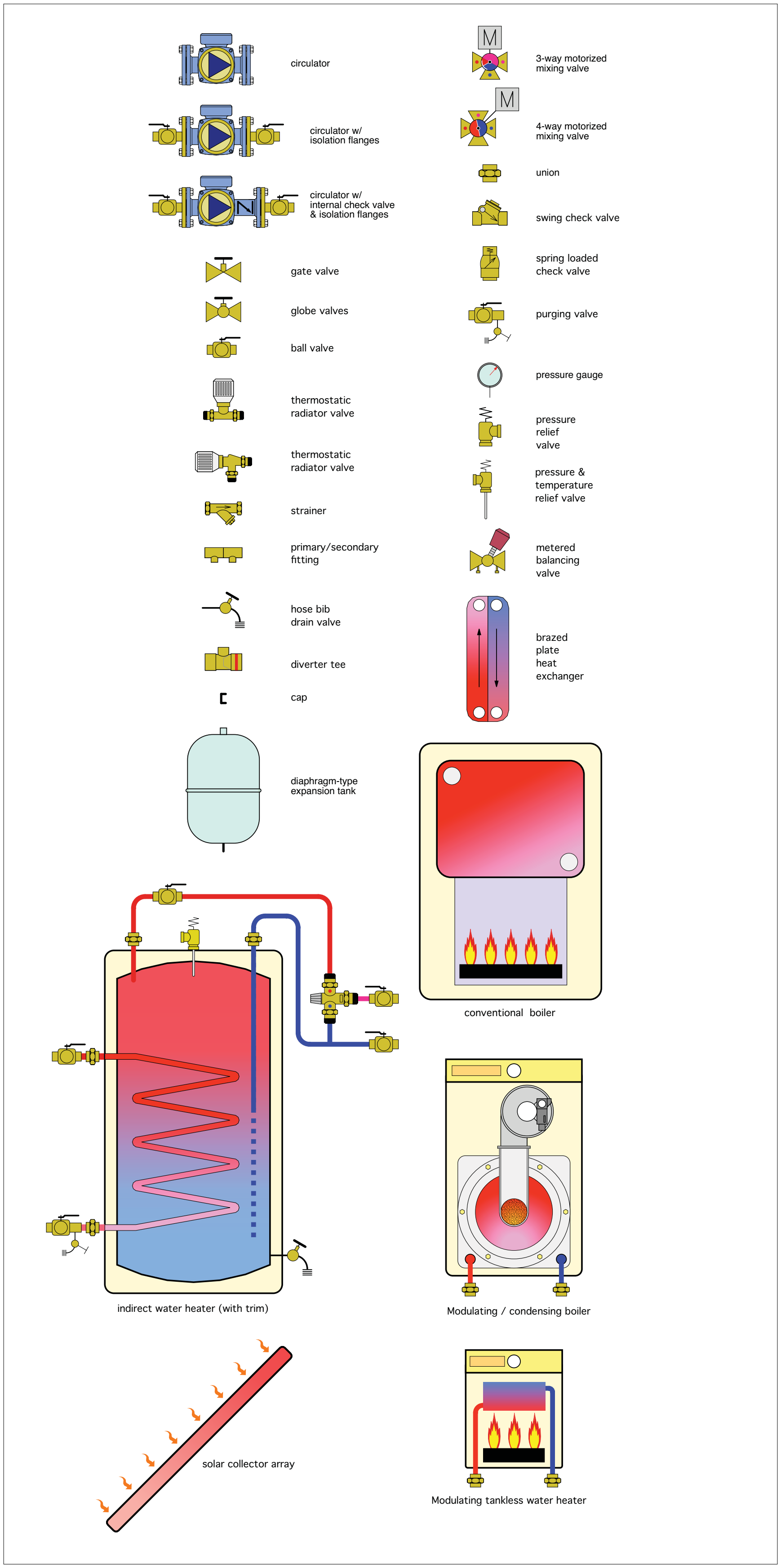
Solar heat intensity:

$$1 \frac{Btu}{hr\ \ ft^2} = 3.15378 \frac{watt}{meter^2}$$

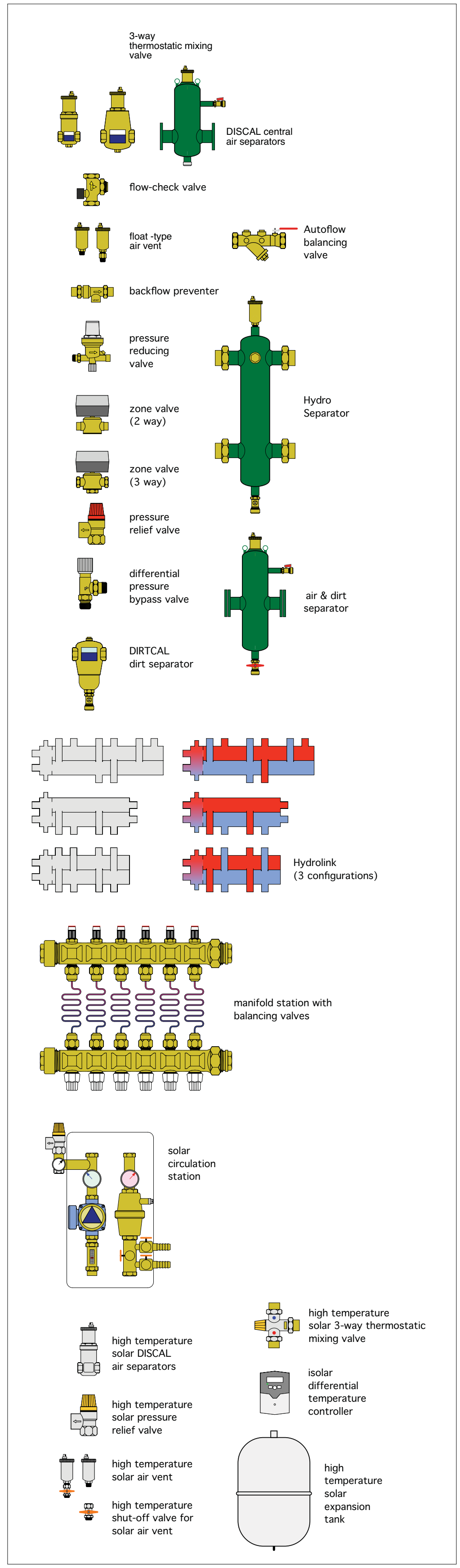
Inlet fluid parameter:

$$1 \frac{^\circ F\ \ hr\ \ ft^2}{Btu} = 0.17615 \frac{^\circ C\ \ m^2}{w}$$

GENERIC COMPONENTS



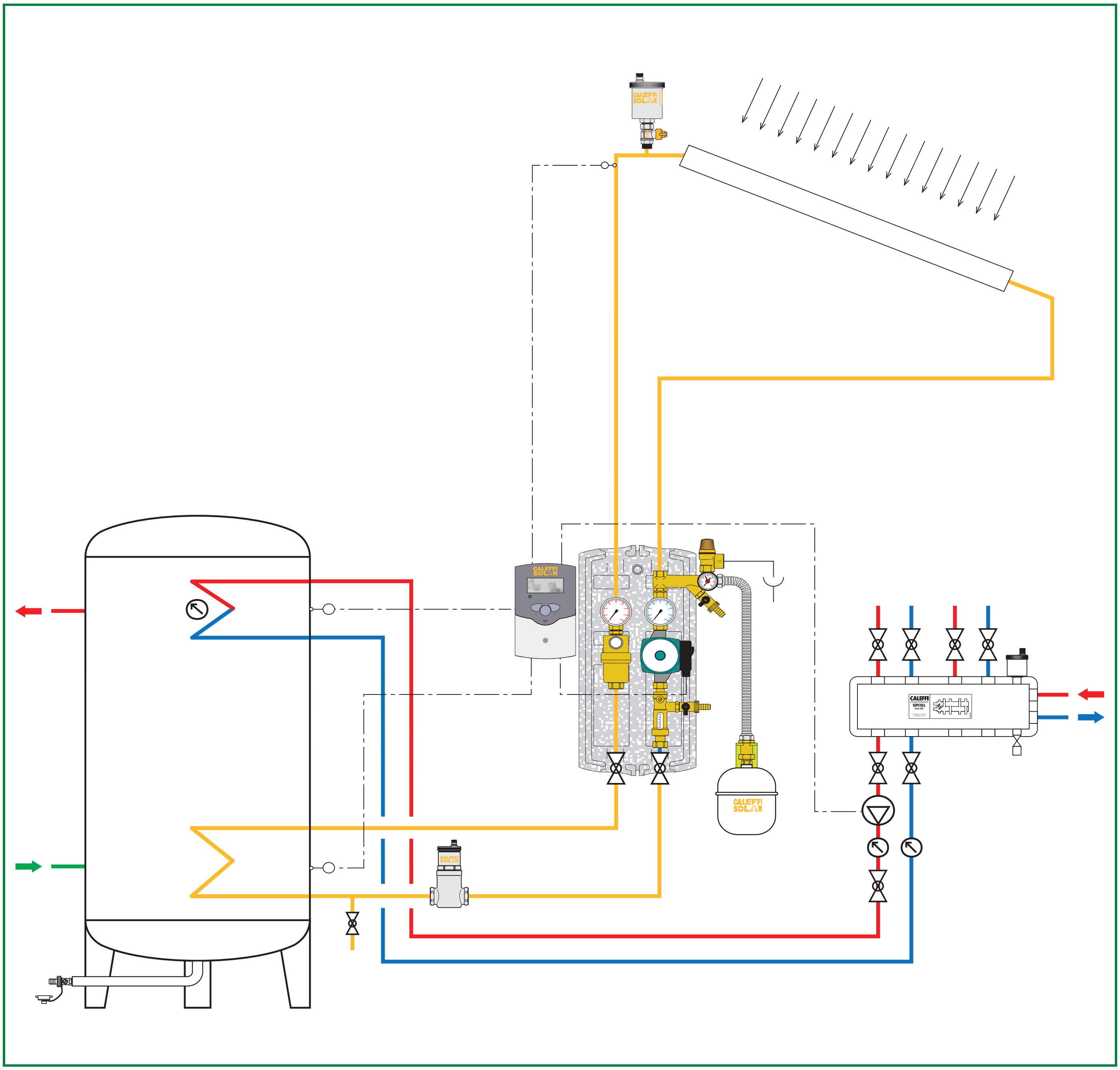
CALEFFI COMPONENTS



CALEFFI SOLAR

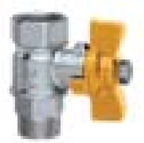
The Caleffi Solar series of products are specifically designed for use in circuits of solar systems. In these systems the heating fluid may contain glycol as additive and may operate at high temperatures.
The materials and components used in its manufacture and the performance of these must be suitable for these operating conditions.

Components for primary circuit - Solutions with glycol



Automatic air vent and shut-off valve for solar systems

250 series



Function

Automatic air vents are used in the closed circuits of solar heating systems to allow air contained in the fluid to be released automatically during the filling process, by means of a valve operated by a float in contact with fluid in the system.
The shut-off valves are used in combination with the automatic air vent vents to be able to isolate them after filling the circuit of solar heating systems.

These series of products have been specially made to work at high temperature with a glycol medium.

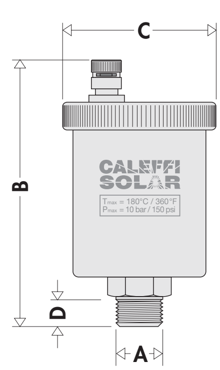
Product range

Code 250041A Automatic air vent for solar systems ____ size 1/2” M NPT
Code NA29284 Shut-off valve for automatic air vent ____ size 1/2” M NPT x 1/2” F NPT

Technical specifications of 250 series valve

Materials: - body:	brass chrome plated
- cover:	brass chrome plated
- control spindle:	stainless steel
- float:	high resistance polymer
- seals:	EPDM
Medium:	water, glycol solutions
Max. percentage of glycol:	50%
Working temperature range:	-20 to 360ºF (-30 to 180ºC)
Max. working pressure:	150 psi (10 bar)
Max. discharge pressure:	75 psi (5 bar)
Connection:	1/2” M NPT

Dimensions

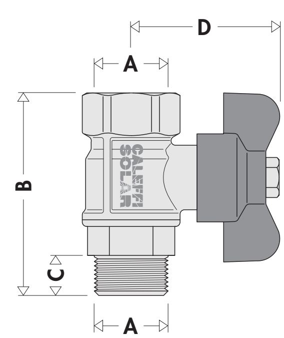


Code	A	B	C	D	Weight (lb)
250041A	1/2"	4"	∅2 1/8"	1/2"	0.7

Technical specifications of valve NA29284

Materials: - body:	brass chrome plated
- ball:	brass chrome plated
- seals:	P.T.F.E.
Medium:	water, glycol solutions
Max. percentage of glycol:	50%
Working temperature range:	-20 to 360ºF (-30 to 180ºC)
Max. working pressure:	150 psi (10 bar)
Connection:	1/2” F x 1/2” M NPT

Dimensions

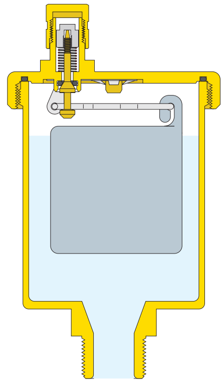


Code	A	B	C	D	Weight (lb)
NA29284	1/2"	2 7/8"	1/2"	1 1/2"	0.5

Operating principle

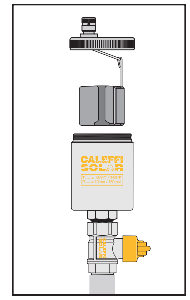
The accumulation of air bubbles in the valve body causes the float to drop so the air vent valve opens.

This phenomenon occurs, and consequently, the valve functions correctly, as long as the water pressure remains below the maximum discharge pressure.



Maintenance

The 250 series automatic air vent is made to allow checking of the internal mechanism. Access to the moving parts that govern the air vent is attained by simply removing the top cover.
A shut-off valve must be installed before the 250 series device to allow shut off to simplify any maintenance work and for shutting off after the filling phase.



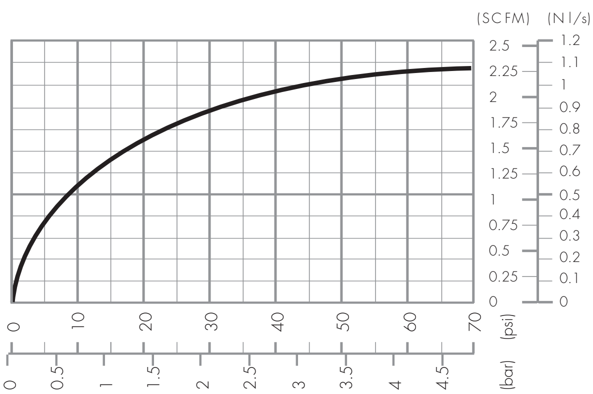
Construction details

Resistance to temperature

The high performance level of this series of automatic air vent valves, required in solar heating systems, is ensured by using materials that are highly resistant to temperature. The materials allow the vent function with glycol water temperatures up to 360°F (180°C).

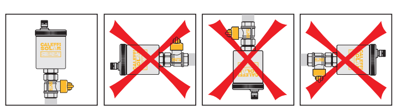
Hydraulic characteristics

Discharge capacity when the system is being filled

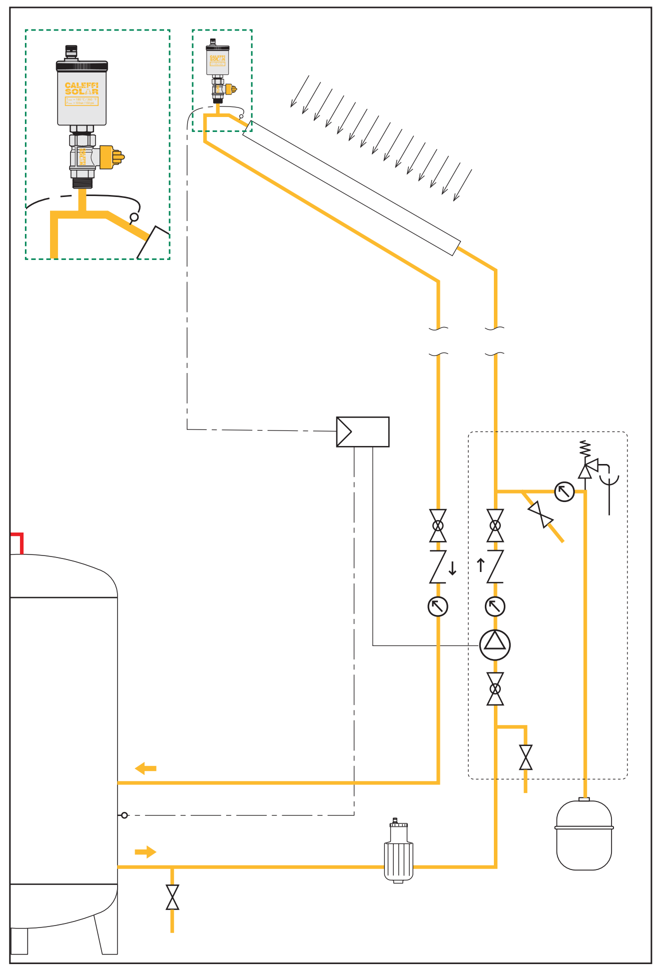


Installation

250 series automatic air vents must be installed in a vertical position, typically on the top of the solar heating system panels and at points in the circuit where air bubbles gather that need to be discharged.
They must always be installed in combination with a shut-off valve. This is necessary since the vent valves must be shut off after use to remove the air during the filling and starting up phase of the system.



Application diagram



SPECIFICATION SUMMARIES

250 series
Automatic air vent for solar heating systems. 1/2" Male NPT connections. Brass body and cover. Chrome plated. Float in high resistance polymer. Seals in high resistance elastomer. Medium: water and glycol solutions. Maximum percentage of glycol: 50%. Working temperature range: -20 to 360°F. Maximum working pressure: 150 psi. Maximum discharge pressure: 75 psi.

Code NA29284
Shut-off valve for automatic air vent for solar heating systems. 1/2" F NPT x 1/2" M NPT connections. Chrome plated brass body and ball. Seals in high resistance elastomer. Medium: water and glycol solutions. Maximum percentage of glycol: 50%. Working temperature range: -20 to 360°F. Maximum working pressure: 150 psi.

Air separators for solar heating systems DISCAL SOLAR

251 series

General

The removal of dissolved gases from a solar primary circuit is an essential process in a solar heating system. The presence of dissolved oxygen in a solar circuit causes rapid localized corrosion in collectors and heat exchangers. Carbon dioxide will dissolve in water, resulting in low pH levels and the production of corrosive carbonic acid. Low pH levels in a solar circuit causes severe acid attack throughout the solar heating system. While dissolved gases and low pH levels in the solar circuit can be controlled by the addition of chemicals, it is more economical and thermally efficient to remove these gases mechanically. This mechanical process is known as air separation and will increase the life of a solar heating system dramatically.

Function

Air separators are used to continuously eliminate air from the primary circuits of solar heating systems. The air vent capacity of these devices is extremely high. They are able to automatically remove all the air from the solar circuits, including microbubbles. The circulation of fully separated fluid allows the system to work under optimal conditions without any trouble with noise, corrosion, local overheating and mechanical damage.

This particular series of air separaots has been specifically designed to work at high temperature with a glycol medium, which is typical of solar heating systems.

Product range

Code 251003A Air separator for solar heating systems with drain .... size 3/4" F NPT

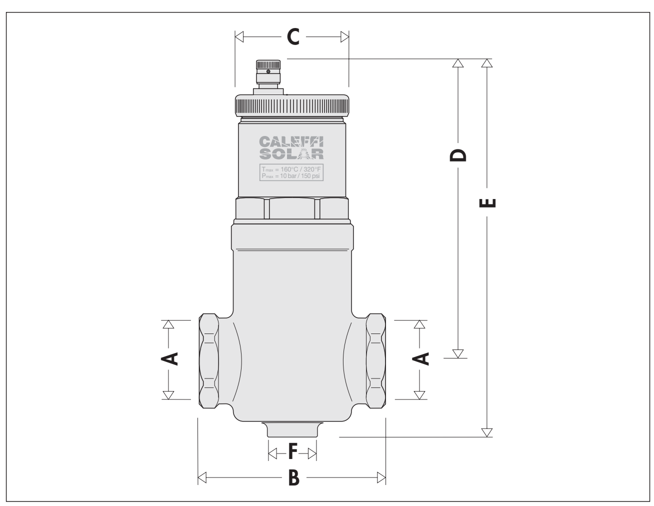
Technical specifications

Materials:	- body:	brass chrome plated
	- cover:	brass chrome plated
	- float:	high resistance polymer
	- internal element:	stainless steel
	- float guide:	brass
	- valve stem:	dezincification resistant brass
	- float lever:	stainless steel
	- spring:	stainless steel
	- seals:	high resistance elastomer

Medium: water, glycol solutions
Max. percentage of glycol: 50%
Working temperature range: -20 to 320°F (-30 to 160°C)
Max. working pressure: 150 psi (10 bar)
Max. discharge pressure: 150 psi (10 bar)

Connections: - Main: 3/4" F NPT
- Drain: 1/2" F NPT

Dimensions



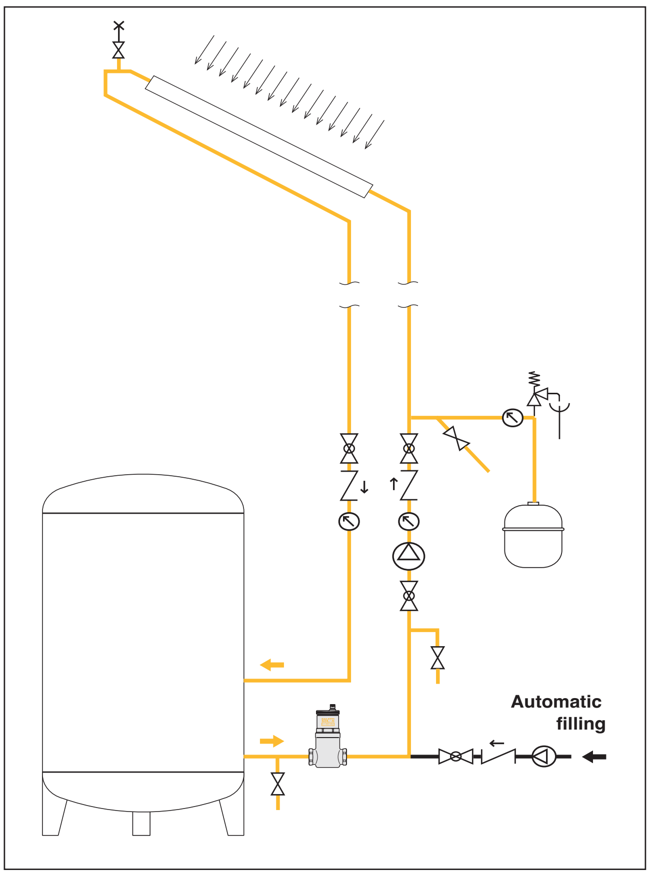
Code	A	B	C	D	E	F	Weight (lb)
251003A	3/4"	3"	2 1/8"	5 5/8"	6 7/8"	1/2"	2.0

The process of air formation

The quantity of air that can remain dissolved in solution in the water depends on the pressure and temperature.
This is known as Henry's law. It may be noted that there is a greater release of air from the solution as the temperature increases and the pressure decreases. This air is in the form of microbubbles with diameters of approximately tenths of a millimeter.
The microbubbles form continuously in the water of the solar heating systems on the top of the panels, because that is the point in the circuit where the highest temperatures are reached.
A portion of the air is re-absorbed as the medium reaches the parts of the circuit at a lower temperature. Because air remain the medium it must be extracted.

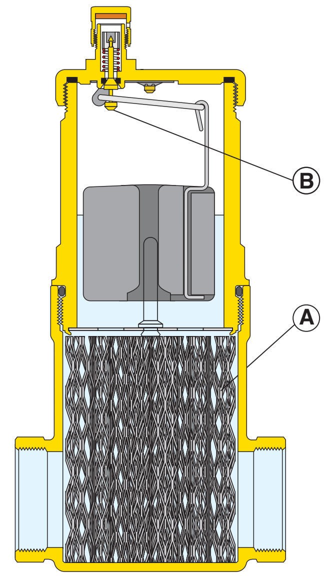
System operation

In solar panel heating systems with forced circulation, it is necessary to expel all the air in the medium during the phases of start up and operation.
The air separator permits separating and expelling this air from the fluid continuously and automatically. Any decrease in pressure due to the release of air is compensated by the expansion tank or automatic filling unit.

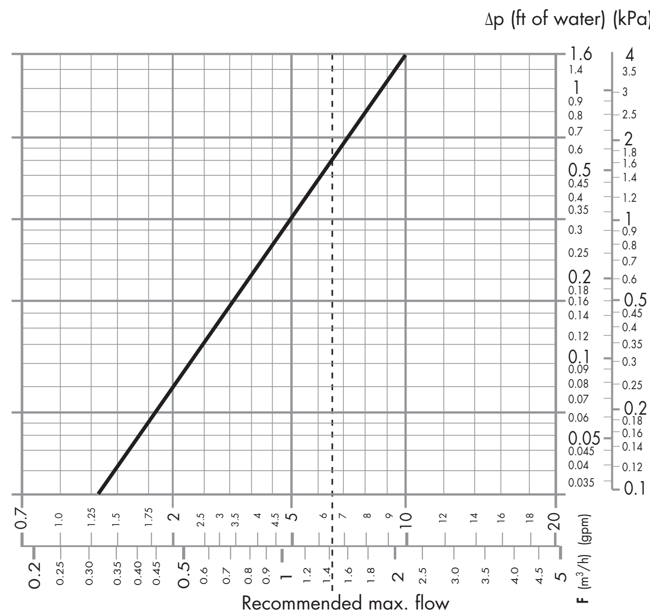


Operating principle

The air separator is composed of a set of metal screen surfaces arranged like spokes (A). This screen creates a swirling motion to assist the release of micro-bubbles and their adhesion to the metal screen. The bubbles join and increase in size until the hydrostatic force increases to overcome the force of adhesion to the screen.
Next, they rise to the top of the chamber where they are released by the float-operated automatic air vent valve (B).



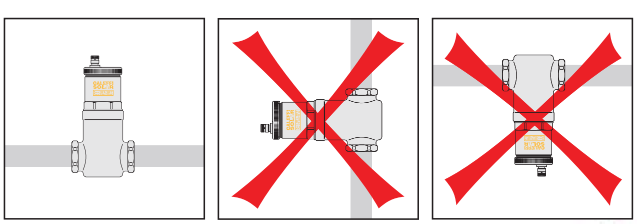
Hydraulic characteristics



The maximum recommended speed of the fluid in the piping is 4.2 ft/sec, which is equivalent to a flow rate of 6.5 gallons per minute.

Installation

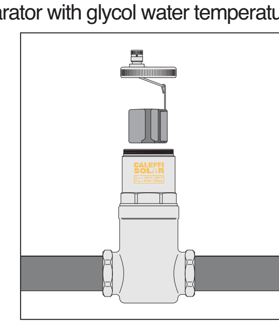
The air separator must always be installed vertically and preferably:
- before the pump to ensure a drop in pressure so microbubbles of air can develop.
- on the return and in the bottom portion of the solar circuit where there is no potential for formation of steam.



Construction details

Resistance to heat and high discharge pressure, allows the maintenance of the functional features of the air separator with glycol water temperatures up to 320°F. The internal geometry of the air separator has been designed to discharge the air up to a pressure of 150 psi.

Discal air separator is built to permit maintenance and cleaning operations without having to remove the valve body from the pipe.
Access to the moving parts that control the air vent is attained by simply removing the top cover.



High-performance automatic air vent DISCALAIR SOLAR

251 series

CALEFFI SOLAR

Function

DISCALAIR solar devices are used in hydronic systems or in the filling and start-up phase of solar heating systems to discharge even large quantities of air that have formed in the circuits. This function is performed even when there is considerable pressure thanks, to the special geometry of the discharge mechanism, which is identical to the mechanism on DISCAL Solar 251 series air separators.

This particular series of automatic air vent valves has been specifically designed to work at high temperatures with a glycol medium, typical of solar heating systems.

Product range

Code 251004A High-performance automatic air vent valve for solar heating systems ______ size 1/2" F NPT

Technical specifications

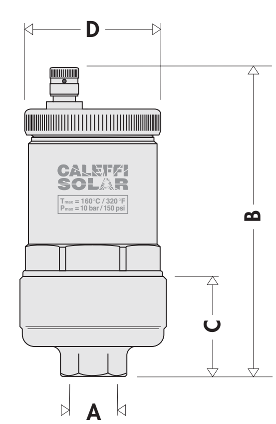
Materials:
- body: brass, chrome plated
- cover: brass, chrome plated
- float: high-resistance polymer
- float guide: brass
- valve stem: dezincification-resistant alloy
- float lever: stainless steel
- spring: stainless steel
- hydraulic seals: high resistance elastomer

Medium: water, glycol solutions
Max. percentage of glycol: 50%

Working temperature range: -20 to 320ºF (-30 to 160ºC)
Max. working pressure: 150 psi (10 bar)
Max. discharge pressure: 150 psi (10 bar)

Connections: 1/2" F NPT

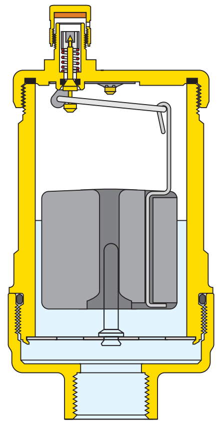
Dimensions



Code	A	B	C	D	Weight (lb)
251004A	1/2"	4 1/2"	1 3/8"	2 1/8"	1.3

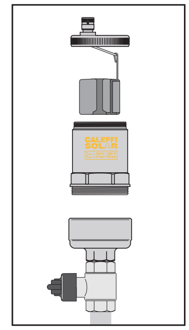
Operating principle

The accumulation of air bubbles in the valve body causes the float to drop so that the valve opens.
This action, and correct air valve valve operation, is ensured as long as the water pressure remains under the maximum discharge pressure.



Maintenance

The DISCALAIR automatic air vent valve is built to permit inspection of the internal mechanism.
Access to the moving parts that govern the air vent is attained by simply removing the top cover. In addition, the body can be separated from the bottom portion connected to the pipe.
A shut-off valve must be installed before the DISCALAIR device to allow for shut off after the filling phase and to simplify any maintenance work.



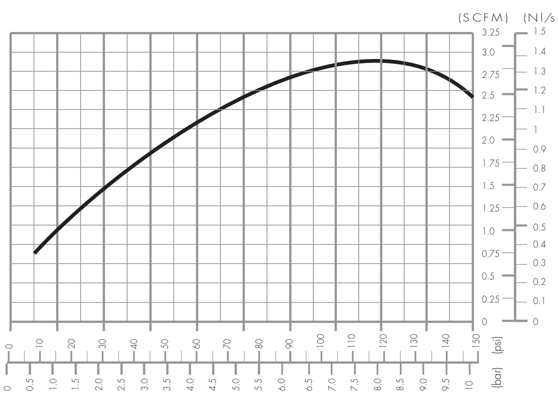
Construction details

Resistance to heat and high discharge pressure

The high performance of this series of automatic air vent valves, required in solar heating systems, is ensured by the use of heat resistant materials.
The materials allow the vent function with glycol water temperatures up to 320°F. The internal geometry of the valve has been designed to discharge air up to a pressure of 150 psi.

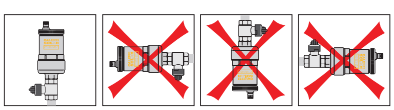
Hydraulic characteristics

Discharge capacity in the phase of filling the system

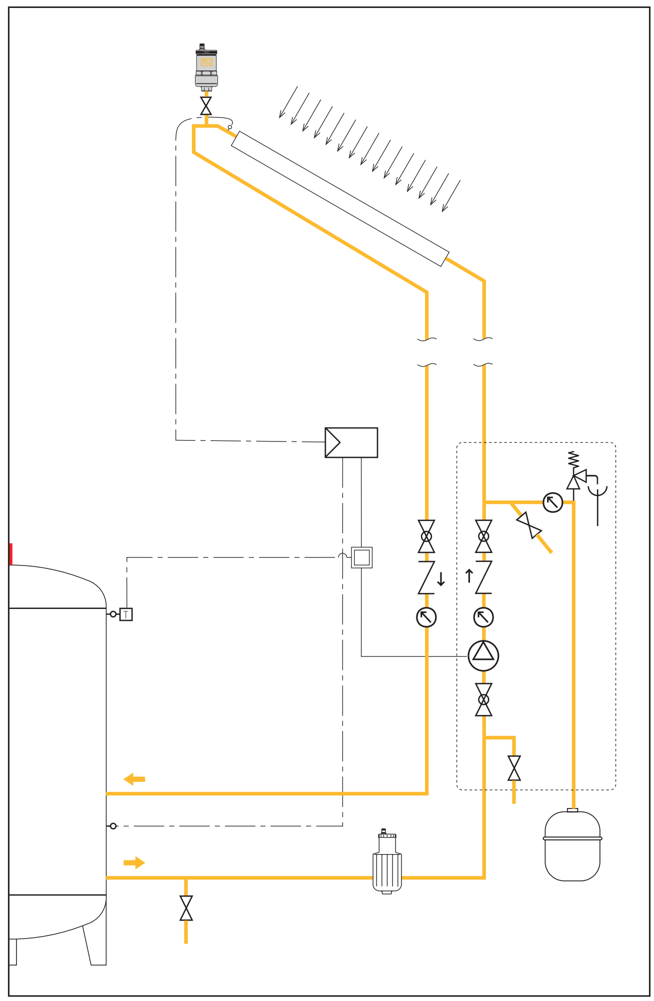


Installation

DISCALAIR series 251 automatic air vent valves must be installed vertically, typically on the top of solar heating system panels and at points in the circuit where bubbles of air gather that must be discharged.
They must always be installed in combination with a shut-off valve. This is necessary since the vent valves must be shut off after use to remove the air as the system is filling and starting up.



Application diagram



SPECIFICATION SUMMARIES

DISCAL*AIR* SOLAR 251 series

High-performance automatic air vent valve for solar heating systems. Connections 1/2" F. Brass body, chrome plated. High resistance polymer float. Stainless steel float lever and spring. Brass float guide. Dezincification-resistant alloy release stem. High resistance elastomer hydraulic seals. Medium water and glycol solutions; maximum percentage of glycol 50%. Temperature range -20 to 320°F. Maximum working pressure 150 psi. Maximum discharge pressure 150 psi.

Adjustable thermostatic mixing valve for solar systems

252 series

General

In solar systems, the temperature in the storage tank can vary considerably, depending on the solar radiation, and can reach very high temperatures over long periods. In summer, and if there is little water usage, the hot water at the storage tank outlet can actually reach temperatures around 200° F. At these temperatures, the hot water cannot be used directly because of the danger of scalding.

Function

The thermostatic mixing valve is used in systems for scald protection in the production of domestic hot water.
It is designed to maintain the set temperature of the mixed water supplied to the user when there are variations in the temperature and pressure conditions of the incoming hot and cold water or in the water's flow rate.
This particular series of mixing valves can function continuously at the high temperatures of the incoming hot water from the solar storage tank.

ASSE 1017

Product range

Code 2521 series Adjustable thermostatic mixing valve for solar systems .... sizes 1/2", 3/4", 1" sweat
Code 2523 series Adjustable high flow thermostatic mixing valve for solar systems .... sizes 3/4", 1" sweat

Technical specifications

Materials:
- body: dezincification resistant alloy brass
- shutter: PSU
- springs: stainless steel
- seal components: EPDM

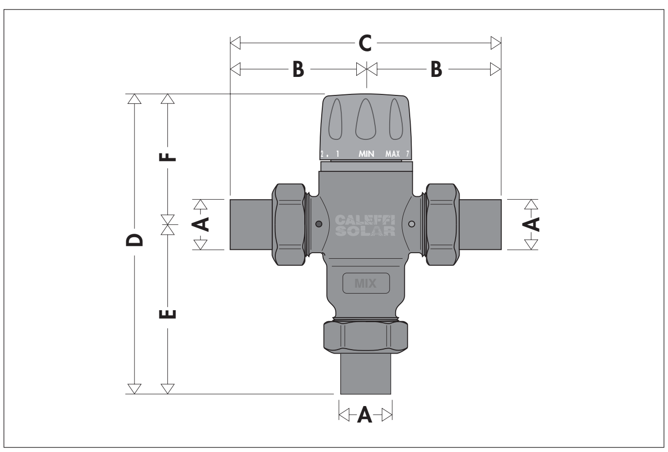
Setting range: 80—150°F (27—65°C)
Accuracy: ± 3°F (2°C)

Max. working pressure (static): 150 psi (10 bar)
Max. working pressure (dynamic): 75 psi (5 bar)
Min. working pressure (dynamic): 30 psi (2 bar)

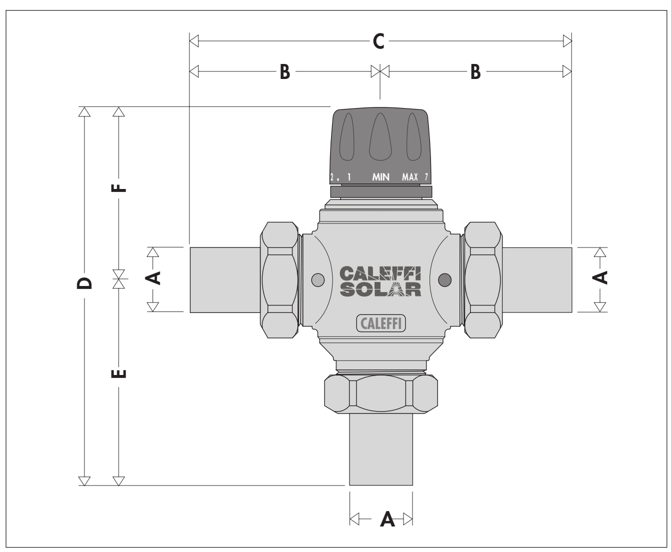
Max. inlet pressures ratio (H/C or C/H): 2:1
Max. inlet temperature: 210°F (100°C)
Min. temperature difference between hot water at inlet and mixed water at outlet for optimum performance: 30°F (15°C)
Min. flow rate to ensure stable temperature:
- 2521 version: 1.3 gpm (5 lpm)
- 2523 version: 2.3 gpm (8.5 lpm)

Connections:
- 2521 version: 1/2", 3/4", 1" with sweat union
- 2523 version: 3/4" and 1" with sweat union

Dimensions



Code	A	B	C	D	E	F	Weight (lb)
2521 49A	1/2"	2 1/4"	4 1/2"	5 5/8"	3 1/8"	2 5/8"	2.2
2521 59A	3/4"	2 1/2"	5"	5 7/8"	3 1/4"	2 5/8"	2.4
2521 69A	1"	3 1/8"	6 1/4"	6 3/8"	3 7/8"	2 5/8"	2.6

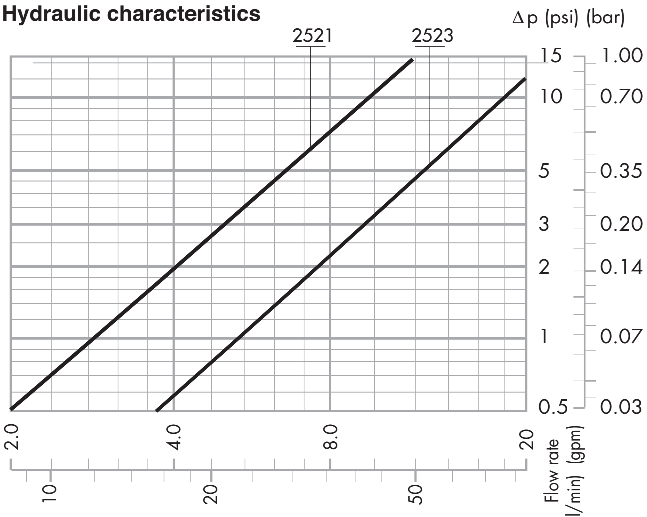


Code	A	B	C	D	E	F	Weight (lb)
2523 59A	3/4"	3 1/8"	6 1/4"	6 3/4"	3 1/4"	3 1/2"	5.3
2523 69A	1"	3 5/8"	7 1/4"	7 1/4"	3 3/4"	3 1/2"	5.6

Operating principle

The controlling element of the solar thermostatic mixing valve is a temperature sensor that is fully immersed in the mixed water outlet passage. As it expands or contracts, the sensor continuously establishes the correct proportion of hot and cold water entering the valve. The flow is regulated by a piston sliding in a cylinder between the hot and cold water passages.
Even when there are pressure drops due to the drawing off of hot or cold water for other uses or variations in the incoming temperature, the mixer automatically regulates the water flow to obtain the required temperature.

Hydraulic characteristics



2521 series Cv 3.0 (gpm) (Kv 2.6 (l/min))
2523 series Cv 5.5 (gpm) (Kv 4.6 (l/min))

Use

Thermostatic mixing valves are typically installed at the outlet of hot water storage tanks in solar systems to ensure constant temperature of the mixed water supplied to the end user. Because of their flow characteristics, the valves can be installed to control the temperature for both single point of use and for point of distribution. In order to guarantee the delivery of mixed water at the set temperature, the thermostatic mixing valves must have a minimum flow rate of:
2521 series min. flow of 1.3 gpm
2523 series min. flow of 2.3 gpm

Installation

Before installing the mixing valve, the pipework must be flushed out to ensure that there are no circulating impurities to harm the system. We recommend always installing filters of sufficient capacity at the inlet of the water system.

Thermostatic mixing valves can be installed horizontally or vertically.

The following are indicated on the body of the mixing valve:
· hot water inlet, indicated with the color red and the word "HOT"
· cold water inlet, indicated with the color blue and the word "COLD"
· mixed water outlet with the word "MIX".

Temperature adjustment

The temperature is set at the desired value by the knob with the graduated scale, located on the top of the valve.

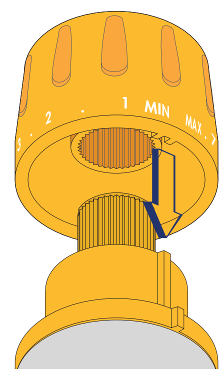
Temperature adjustment table

Position	Min.	1	2	3	4	5	6	7	Max.
T (°F)	80	90	100	110	120	130	135	145	150

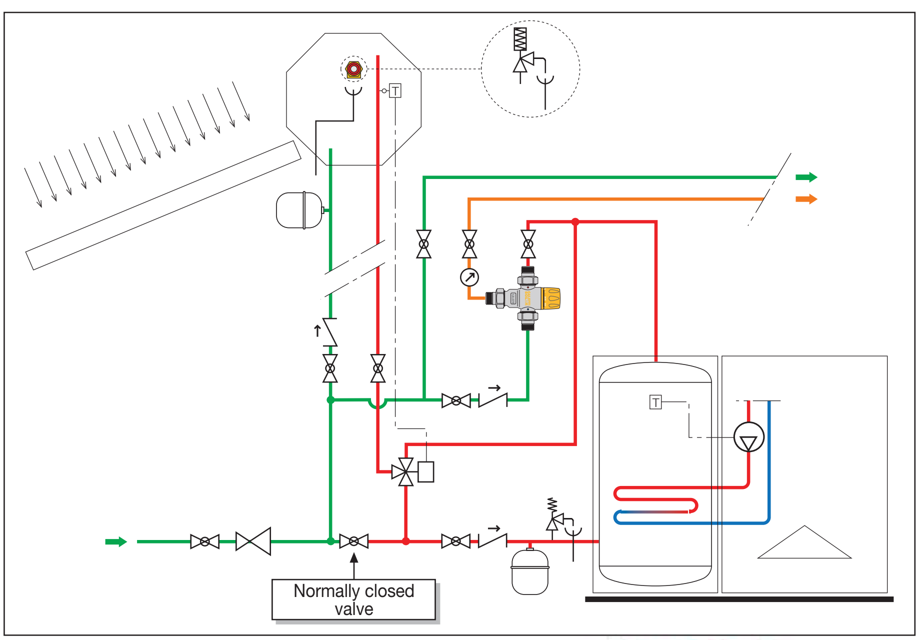
Reference values: T_{hot} = 155°F; T_{cold} = 55°F; Hot and cold water inlet pressures = 45 psi

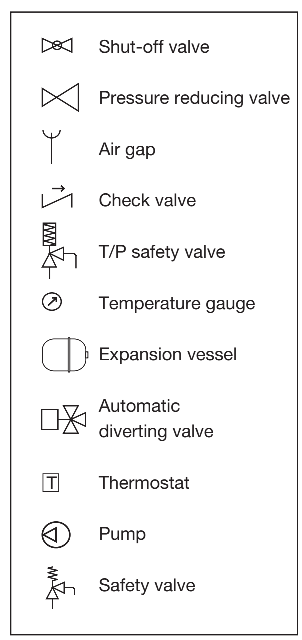
Locking the setting

After selecting the temperature, the setting can be locked at the desired value using the control knob.
To do this, unscrew the lock screw on the upper part of the control knob, remove the knob and put it back on so that the internal reference couples with the protrusion on the knob carrier ring nut.



Application diagrams - System with thermal integration





Differential temperature controllers
iSolar

257 series

Function

A multi-functional temperature differential controller with add-on system functions, the iSolar series can be used for a wide variety of applications and has inputs for four PT1000 sensors. Preset factory defaults are defined for control of a standard solar water heating system with a second relay (some models) to divert any surplus heat. The auxiliary relay can be used to maintain the tank temperature, protect the system from overheating, or use another source to heat the storage tank.

This controller features a large Liquid Crystal Display (LCD) user interface with three function keys. The easy-to-use icons assist to operate and customize a solar heating system.

Tested and Approved by TÜV Rheinland as an approved U.S. Nationally Recognized Testing Laboratory (NRTL) Exceeds or is equivalent to:
UL 60730-1A
CAN/CSA E60730-1

Product range

Code 257210A iSolar1 controller with 1 standard output relay for pump control, includes 3 temperature sensors
Code 257220A iSolar2 controller with 1 electronic output relay for pump speed control, includes 3 temperature sensors
Code 257230A iSolar3 controller with 2 standard output relays for pump control, plus valve or second pump control, includes 3 temp. sensors
Code 257260A iSolarPlus controller with 2 electronic output relays for pump speed control, plus valve or second pump control, includes 3 sensors

Technical specifications

Housing plastic:	PC-ABS
Protection type:	Indoor only
Mounting:	wall or in 255 series pump station
Display:	LCD with symbols and text
Interface:	three soft push buttons
Inputs:	4 temperature sensors
Outputs:	1 or 2 electronic or standard relays
Switching relay capacities:	2 (1) A 115V
Power supply:	115 V - 60 Hz
Bus interface:	V-Bus

Performance

ΔT adjustment range:	2···40° Ra (1···20°K)
Min. temperature differential	2° Ra (1°K)
Hysteresis:	2° Ra, ± 1° Ra (1°K, ± .5°K)
Max. tank temperature range:	35···205°F (2···95°C)
Max. collector temperature range:	210···375°F (100···190°C)
Emergency shut down of the collector:	230···395°F (110···200°C)
Min. collector temperature range:	50···195°F (10···90°C)
Antifreeze temperature option:	15···50°F (-10···10°C)
kWh (BTU) flow input:	0···5 gpm (0···20 lpm)
Agency approvals	cTÜVus

Temperature sensors

Platinum RTD type:	1,000 ohm
Collector sensor working range:	-58···355°F (-50···180°C)
Tank sensor working range:	15···175°F (-10···80°C)
Length of collector cable:	60 in. (1.5 m)
Length of tank sensor cable:	95 in. (2.5 m)

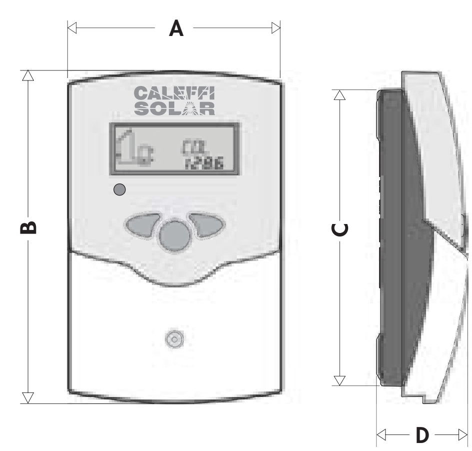
Resistance values for sensors subject to the temperature

°F	14	23	32	41	50	59	68	77	86
Ω	961	980	1000	1019	1039	1058	1078	1097	1117

°F	95	104	113	122	131	140	149	158	167
Ω	1136	1155	1175	1194	1213	1232	1252	1271	1290

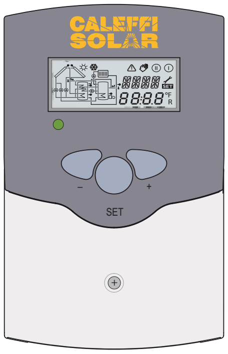
°F	176	185	194	203	212	221	230	239	248
Ω	1309	1328	1347	1366	1385	1404	1423	1442	1461

Dimensions



Code	A	B	C	D	Weight (lb)
250041A	4 3/8"	6 3/4"	6"	2"	0.9

Characteristics



User-friendly operation

System screen LCD display with 16-segment display and 8 symbols for system status

Operating LED control lamp

3 push-button controls

Attractive design and compact dimensions

Easy to install

Standard operation functions

ΔT control - When the switch-on difference is reached, the pump is activated until the differential temperature drops below.

Maximum tank temperature - When the adjusted maximum tank temperature is exceeded, the pump switches off.

Collector emergency shutdown - If adjusted collector temperature is exceeded, the solar pump is switched off.

System cooling - If the temperature rises to the maximum collector temperature the solar pump remains on until the temperature drops.

Minimum collector temperature - a minimum set temperature which must be exceeded before the solar pump is switched-on.

Antifreeze function - If the adjusted temperature drops, the solar pump is switched on to protect the fluid from freezing.

Tank cooling function - In the evening, the solar pump continues running until the storage tank is cooled down.

Tube collector function - The controller measures an increase of heat rise in the collector and adjusts operation for maximum efficiency.

Heat generation measurement kWh (BTU) - The heat generated is measured by the flow and the temperature of feed and return sensors.

Operating hours counter - Operating hours counter stores the solar operating hours of the respective relay.

Manual operating mode - For control and servicing, the operating mode of the controller can be switched manually.

Advanced operation functions (some two-relay models)

Heat dumping function - Heat dumping works independently from the solar operation and activates the second relay.

Backup heating function - Backup heating works independently from the solar operation and activates the second relay.

Second independent ΔT control - The differential temperatures can be adjusted separately.

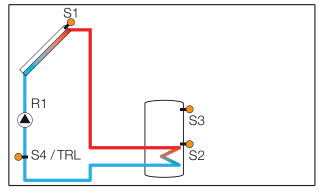
Priority tank / tank rotation - The controller checks the temperatures and rotates or gives priority to charging two tanks.

East / West collectors - Two separate ΔT controls activate each solar pump based on collectors and the one-tank temperature.

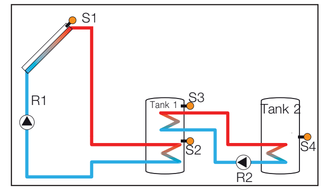
Pump speed control functions (some models)

Pump speed control can improve system efficiency by reducing the flow to the collectors on cloudy days to improve solar thermal transfer and reduce electrical consumption. This is achieved by the differential temperature value between the collectors and storage tank.
If the value for the ΔT switch-on is reached (e.g. ΔT on = 9°), the pump will start with 100% pump speed for 10 seconds, then reduce the speed to the adjusted minimum pump speed (min. pump speed = 30 %, adjustable).
If the temperature difference reaches the set value (e.g. ΔT Set = 18°), pump speed will increase by 10 %. At any further rise of 3° ΔT the pump speed will increase by 10% until the maximum of 100% is reached.

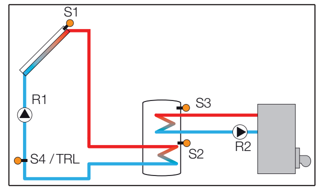
Selectable systems



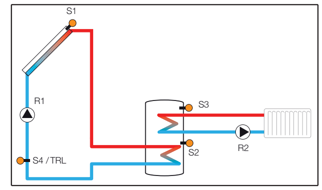
Standard system with 1 tank, 1 pump and 3 sensors. S4 / TRF can be used as BTU meter



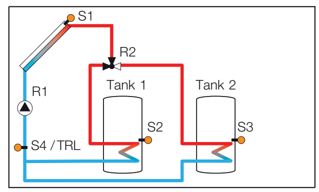
System and heat exchange with an existing tank with 1 tank, 4 sensors and 2 pumps



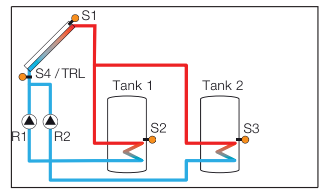
Solar system and backup heating with 1 tank, 3 sensors. S4 / TRF can be used as BTU meter



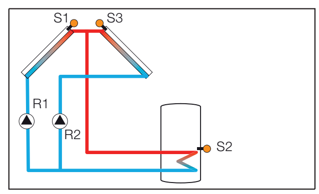
Solar system and heat dumping with 1 tank, 3 sensors. S4 / TRF can be used as BTU meter



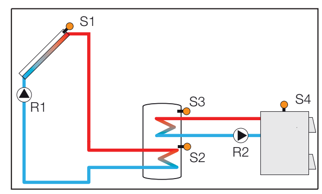
2-tank-solar system with valve logic, 3 sensors, 1 solar pump and 3-way valve. Sensor S4 / TRF can used as BTU meter



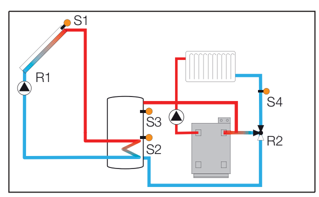
2-tank solar system with pump logic, 3 sensors and 2 solar pumps



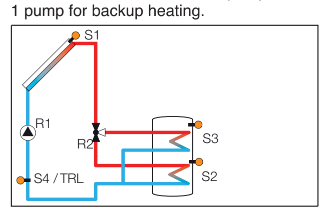
Solar system with east-west collectors, 1 tank, 3 sensors and 2 solar pumps.



System with backup heating by wood boiler with 1 tank, 4 sensors, 1 solar pump and 1 pump for backup heating.



System and heating circuit pre-heat with 1 tank, 4 sensors, 1 solar pump and 3-way valve for heating circuit.



System and tank charge in layers with 1 tank, 3 sensors, 1 solar pump and 3-way valve. Sensor S4 / TRF can be used as BTU meter

Model selection

	iSolar 1	*iSolar 2*	*iSolar 3*	*iSolar Plus*
Selectable programs	1	1	2	9
Electronic relay	0	1	0	2
Standard relay	1	0	2	0
Pump speed control	no	yes	no	yes
Operating hours counter	yes	yes	yes	yes
kWh (BTU) measurement	yes	yes	yes	yes
V-bus for data recorder	yes	yes	yes	yes
PC-interface RS232	yes	yes	yes	yes
Heat dumping function	no	no	yes	yes
Backup heat function	no	no	yes	yes
Additional ΔT control	no	no	no	yes
Two-tank priority	no	no	no	yes
Clock with scheduling	no	no	no	yes
Code	257210A	257220A	257310A	257260A

Solar pump stations for solar heating systems

255 - 256 series

(Daul station with cover and controller)

General

The solar pump station is a pre-installed and leak-tested unit with fittings for transferring heat from the collector to the storage tank. It contains important fittings and safety devices for the operation of the solar thermal system:

- Ball valves in flow and return in combination with check valves to prevent gravity and thermo circulation.
- Unit for flushing, filling and emptying the system.
- Air vent for manual bleeding of the solar thermal system.
- Flow meter for displaying and setting the flow rate.
- Thermometer in flow and return for displaying both temperatures.
- Pressure gauge for displaying the system pressure.
- Safety relief valve to prevent overpressure.
- Three-speed solar pump for wide range of flow rates.

Function

Solar pump stations are used on the primary circuit of solar heating systems to control the temperature of the hot water storage. The pump inside the units is activated by the signal from the differential temperature controller. The units contain the functional and safety devices for an optimal circuit control, and ar available with flow and return connection and with return connection only.

Product range

Code 255056A	Dual pump station, flow and return connection, flow meter scale: 1/2–5 gpm	size 3/4” M NPT unions
Code 255059A	Dual pump station, flow and return connection, flow meter scale: 1/2–5 gpm	size 3/4” sweat unions
Code 255060A	Dual pump station, flow and return connection, flow meter scale: 1/2–5 gpm	size 1” male half unions
Code 256059A	Single pump station, return connection, flow meter scale: 1/2–5 gpm	size 3/4” sweat unions

Technical specifications

Body:	brass
Temperature gauge:	steel / aluminium
Seals:	PTFE / EPDM
O-Rings:	EPDM / Viton
Union gaskets:	AFM 34, asbestos free
Insulating shell:	EPP, thermal conductivity value = R4

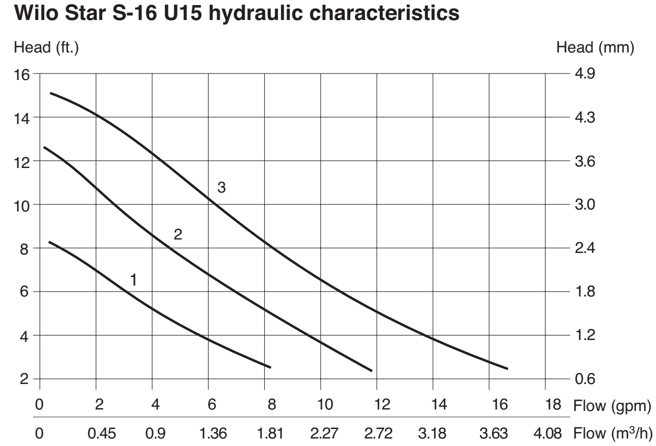
Performance

Medium:	water, glycol solutions
Max. percentage of glycol:	50%
Max. working temperature:	360°F (180°C)
Max. working pressure:	150 psi (10 bar)
Safety relief valve temperature range:	-20 to 360°F (-30 to 180°C)
Safety relief valve factory setting:	90 psi (6 bar)
Min. opening pressure for check valve:	Δp: 1/4 psi (2 kPa)
Adjustment range of flow meter:	1/4 to 5 gpm (1 to 20 l/min)
Max return flow meter temperature:	265°F (130°C)
Pressure gauge scale:	0–90 psi (0—6 bar)
Temperature gauge scale:	32–320°F (0—160°C)
Connections:	1” male half union
Filling/drain hose connections:	3/4”

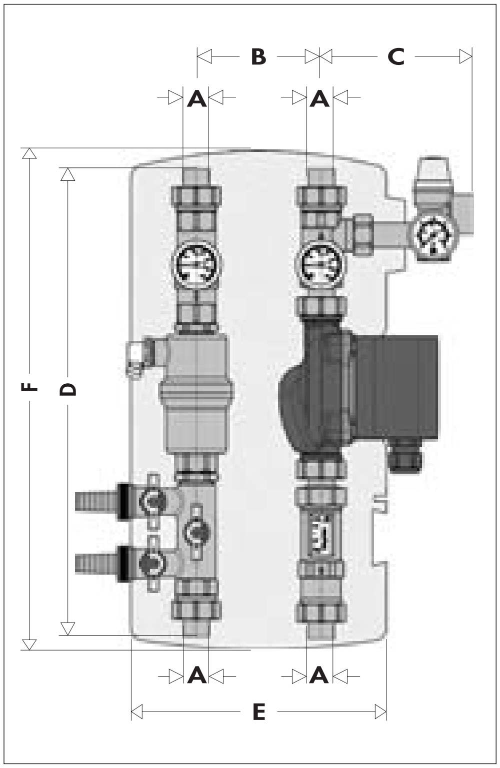
Wilo pump

Wilo solar model:	Star S-16 U15
Body:	cast iron
Power supply:	115 V - 60 Hz
Max. pressure:	150 psi (10 bar)
Max. temperature:	230°F (110°C)
Agency approval:	cULus

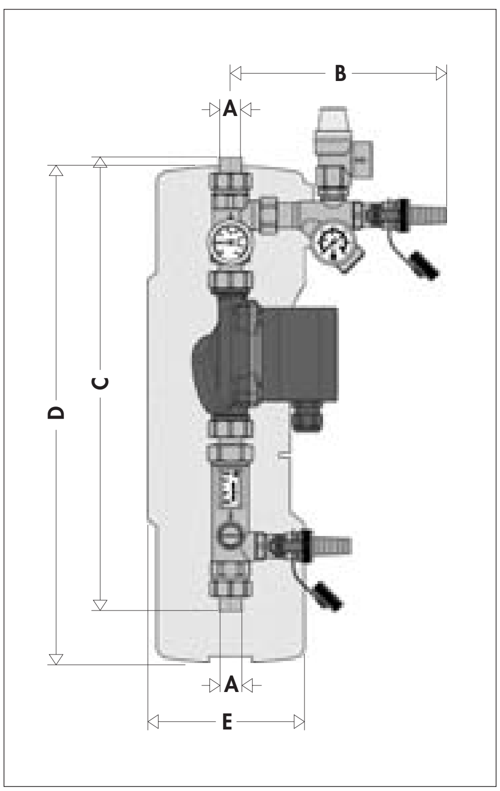
Wilo Star S-16 U15 hydraulic characteristics



Dimensions

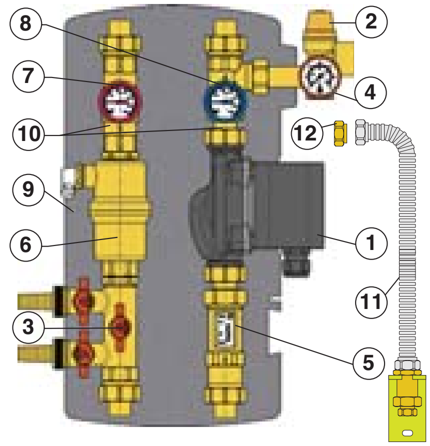


Code	A	B	C	D	E	F	Weight (lb)
255056A	3/4"	4"	4 7/8"	15"	8"	16"	15
255059A	3/4"	4"	4 7/8"	15"	8"	16"	15
255060A	1"	4"	4 7/8"	13"	8"	16"	15



Code	A	B	C	D	E	Weight (lb)
256059A	3/4"	7"	16 1/4"	17"	5"	10

Characteristic components

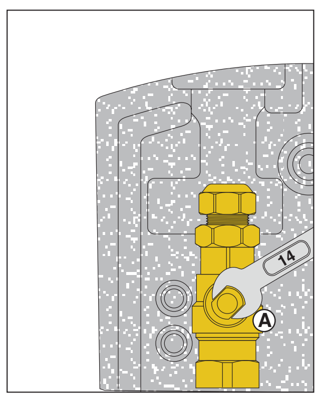


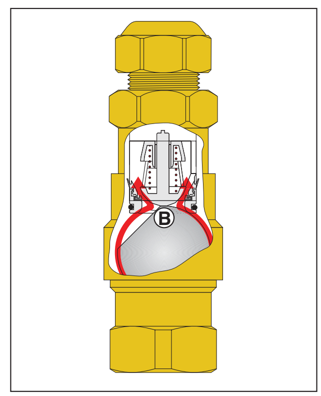
1 Wilo-Solar circulation pump
2 Safety relief valve 253 series
3 Filling/drain valve
4 Pressure gauge
5 Flow meter
6 Air trap and vent
7 Flow temperature gauge
8 Return temperature gauge
9 Pre-formed insulation shell
10 Shut-off and check valve
11 Expansion Tank connection kit
12 3/4" plug (used if no expansion tank is installed)

Construction details

The shut-off and check valves are built into the ball valves of the temperature gauge connectors.

To allow the fluid to flow in both directions, it is necessary to open the respective ball valve (A) to 45° with a 14mm wrench. The check valve is opened by the ball (B). In normal system operation, the ball valves must be fully open.

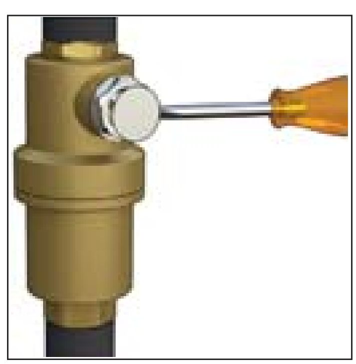


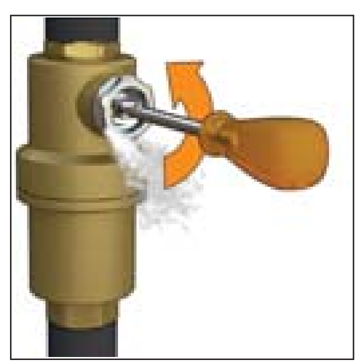


Air trap

The solar pump unit version with flow and return connection is equipped with an air trap on the flow line. The gases, separated from the fluid, are collected at the top of the trap.

The collected gases must be released from time to time - every day after the initial installation; however, it can eventually be done weekly or monthly, depending on the quantity of the air. The collected gases are released using the manual air vent with a screwdriver. To maintain optimal efficiency of the solar heating system, it is necessary to vent the system every six months by using the manual air vent.





Safety relief valve for solar systems

253 series

CALEFFI SOLAR

CALEFFI

General

The safety relief valves manufactured by Caleffi are produced in compliance with the essential safety requirements of the Directive 97/23/EC of the European Parliament and the Council of the European Union for the Harmonization of Member States with regard to pressurized equipment.

Function

These safety relief valves are used to control pressure in the primary circuits of solar heating systems.
When the calibrated pressure is reached, the valve opens to release the fluid into the atmosphere and prevents the pressure in the system from reaching levels that might damage the solar collectors and equipment.
These particular series of products have been specially made and certified to work at high temperature with a glycol medium.

CE 1115 TÜV Rheinland

TÜV Rheinland is an approved U.S. Nationally Recognized Testing Laboratory (NRTL) Certification Body for Pressure Equipment

Product range

253 series Safety relief valve for solar systems ____ size 1/2” F x 3/4” F

Technical specifications

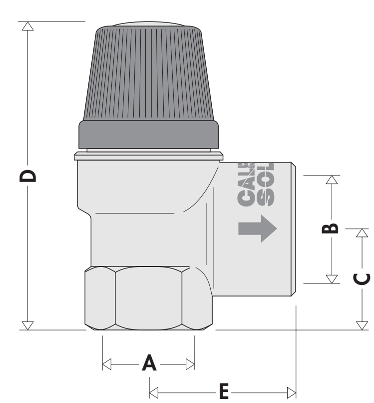
Materials: - body:	brass chrome plated
- control spindle:	brass
- relief seal:	high resistance elastomer
- spring:	stainless steel
- control knob:	PA6G30
Medium:	water, glycol solutions
Max. percentage of glycol:	50%
Normal pressure:	150 psi (10 bar)
Working temperature range:	-20 to 360°F (-30 to 180°C)
PED section:	IV
Approval:	according to TÜV SV 07 2009 TÜV • SOL • 50 • p
Connections:	1/2” F x 3/4” F

Performance

Opening overpressure:	10%
Closing differential:	20%
Discharge capacity:	171,000 BTU (50 kW)

Code	253043	253044	253046	253048	253040
Preset psi (bar)	45 (3)	60 (4)	90 (6)	120 (8)	150 (10)

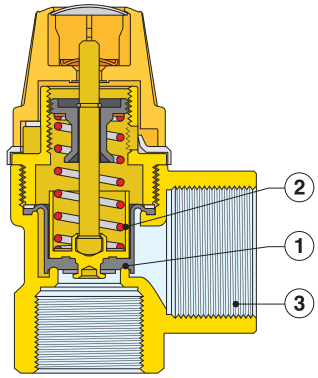
Dimensions



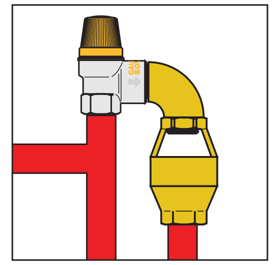
Code	A	B	C	D	E	Weight (lb)
25304_	1/2"	3/4"	1"	2 3/4"	1 3/8"	0.3

idronics

Operating principle
The valve disk (1), pressed by a preset spring (2), raises off the seat when reaching the preset pressure and fully opens the outlet vent. The preset pressure is chosen according to the maximum permissible pressure in the solar heating system.
The diameter of the outlet connection (3) is greater than the inlet in order to help discharge the required volume.
As the pressure decrease, the opposite action, occurs with the valve subsequently closing within the preset tolerances.



Discharge pipe
This valve should only be used and properly installed so that spillage of glycol could not cause damage. To avoid damage due to valve operation, a discharge pipe must be installed. It should terminate approximately 12" (305mm) above an appropriate container or through an air gap, as shown in the diagram, piped into a suitable container or other suitable place of disposal. Under no circumstances should the vent opening or drain line be plugged.



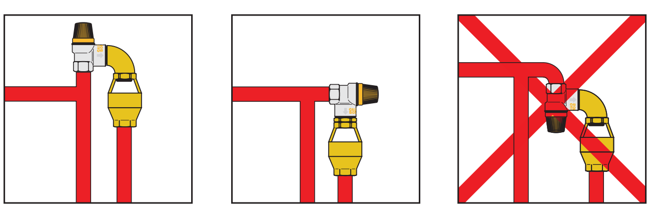
Construction details

Temperature and glycol
In solar systems, heating fluid of the primary circuit contains glycol as an additive and operates at high temperatures. Because of these particular operating conditions, the valve disk seal of the safety valve is made of high resistance elastomer.
The knob is made of plastic material especially resistant to increases in temperature and to UV rays, in the case of outdoor installations.

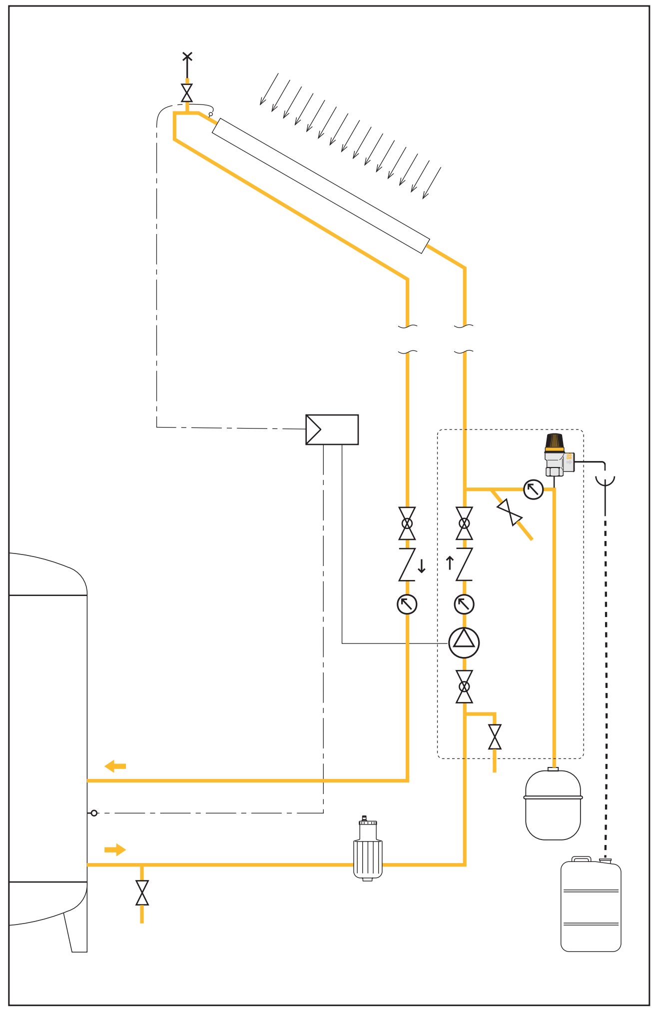
Chrome plating
The valve body is chrome plated to protect it from dirt and moisture, in the case of outdoor installations of solar heating systems.

Certification
253 series safety relief valves are certified for specific use in solar heating systems by the certifying body TÜV, in accordance with standard SV 100 Ed. 10.01 par. 7.7. TÜV Rheinland is an approved U.S. Nationally Recognized Testing Laboratory (NRTL)

Installation
The safety relief valves for solar systems must be installed near the point in the circuit where the system is filled - before the expansion tank.
Make sure there are no shut-off devices between the valve and the rest of the system.
The safety relief valves can be fitted vertically or horizontally but not upside down. This prevents deposits of impurities from affecting correct functioning.
The safety relief valves must be installed in line with the flow direction indicated by the arrow on the valve body.



Application diagram



SPECIFICATION SUMMARIES

253 series
Safety relief valve for solar heating systems. CE mark as per Directive 97/23/EC. TÜV certified for solar systems. 1/2” F x 3/4” F threaded connections. Brass body. Chrome plated. Diaphragm and disk seal in high resistance elastomer. Spring of stainless steel Control knob of PA6G30. Temperature range: -20 to 360°F (-30 to 180°C). Nominal pressure: 150 psi (10 bar). Calibration setting: 45, 60, 90, 120, 150 psi (3, 4, 6, 8, 10 bar). Medium: water and glycol solutions. Maximum percentage of glycol: 50%.

Expansion tanks for pressurized systems SolarPlus

259 series

General

Modern solar heating systems can reach temperatures of up to 385°F during inactivity. The rsult is the vaporization of the solar liquid and extreme temperatures in the solar circuit, up to the solar station. This damages parts of the system, including pumps, connection joints and the diaphragm in the expansion tank. Furthermore, in the event of prolonged heat absorption, for example in the summer, when on vacation or if the electricity is out, the pressure of the solar system can increase to the point of activating the safety relief valve. In order to support the highest possible inactivity temperatures, the special heat-resistant diaphragm in the SolarPlus expansion tank can withstand temperatures up to 210°F.

Function

The diaphragm pressure expansion tank ensures that the system pressure does not exceed or drop below the limits established in the system design. The diaphragm divides the space inside the tank occupied by the pre-charged gas and the solar fluid. When the volume of the solar fluid expands because of the heat, the diaphragm stretches into the gas chamber. As a result, the space available for the solar fluid increases and the pressure inside the system remains constant at the designed value. When the volume of the solar fluid decreases because of cooling, the diaphragm returns to the correct initial pre-charged pressure.

Product range

Code 259 series SolarPlus expansion tanks for pressurized solar heating systems ______ sizes 3, 5, 7, 9, 13 gallons

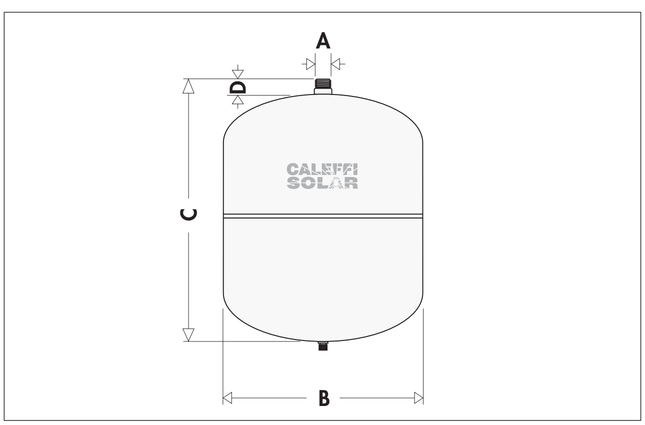
Technical specifications

Materials: - body: welded steel
- coating: epoxy paint
- diaphragm: EPDM

Medium: water, glycol solutions
Max. percentage of glycol: 50%

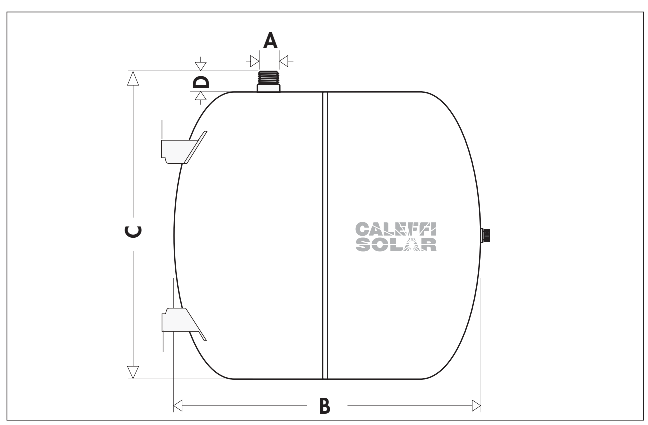
System temperature range: 15...250°F (-10...120°C)
Max. diaphragm temperature: 210°F (100°C)
Max. working pressure: 150 psi (10 bar)
Pre-charged pressure: 35 psi (2.5 bar)
Connection: 3/4" M

Dimensions



Code	A	B	C	D	Size (gal)
250012	3/4"	10 5/8"	10 5/8"	3/4"	3
250018	3/4"	10 5/8"	13 3/4"	3/4"	5
250025	3/4"	11 7/8"	15 1/2"	3/4"	7

Dimensions

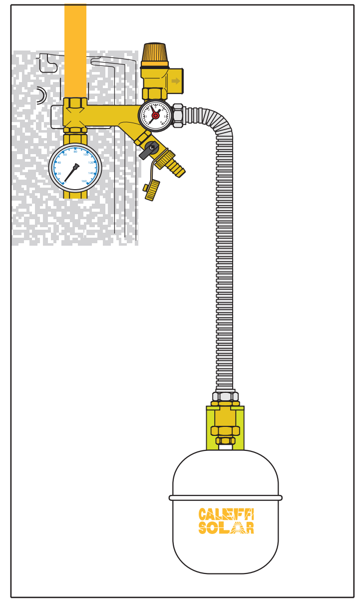


Code	A	B	C	D	Size (gal)
259035	3/4"	15 3/4"	16"	1"	9
259050	3/4"	21 1/8"	16"	1"	13

Mounting feet for wall installation.

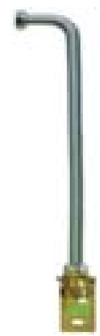
Installation

The expansion tank can be installed after the flow check valve on the outlet side of the circulation pump, between the solar collector (exit pressure), or it can be on the inlet side of the circulation pump (entrance pressure). Since there can be no check valve between the collector and the expansion tank, the expansion tank should be installed on the outlet side of the pump (exit pressure).



Accessories

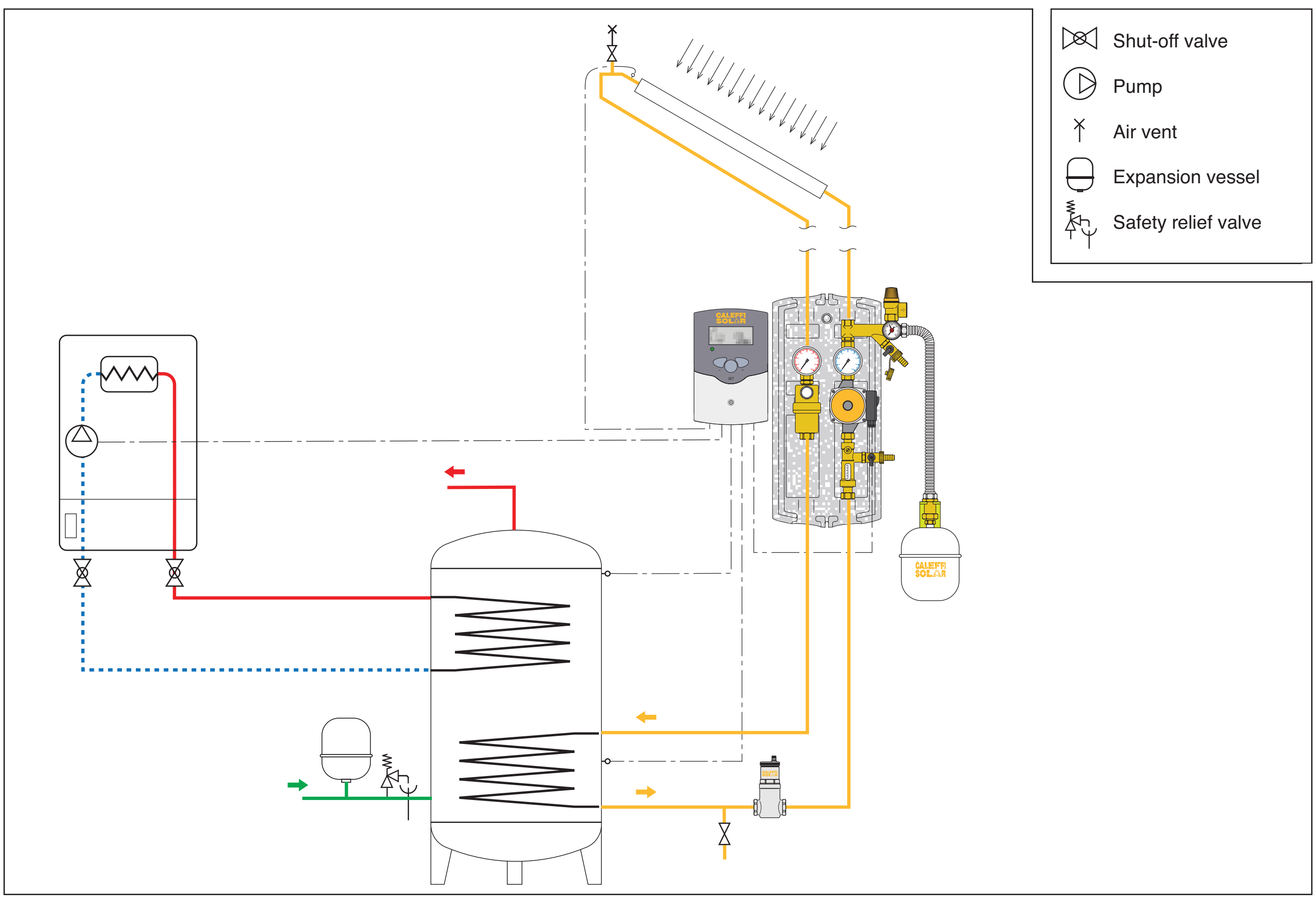
A expansion tank connection kit, consisting of a flexible stainless steel hose, a double automatic shut-off valve, wall bracket and mounting hardware, helps reduce installation time and provides suitable mounting.



Code: 255001

Max. working pressure:	150 psi (10 bar).
Max. check valve working temperature:	250° F (120°C).
Hose length:	20 in. (500 mm).
Connections:	3/4” straight.

Bracket for expansion tank with a maximum capacity of 7 gallons.



Flexible stainless steel insulated piping SolarFlex

NA3540-15

Function

SolarFlex is a system solution with pre-insulated flow and return pipes for solar hot water heating systems used to connect the solar collector with the storage tank in an easy, quick and professional way. It optimizes thermal efficiency of the entire system. The pre-insulation solution of two flexible stainless steel pipes inside two EPDM closed cell insulation and the integrated sensor cable, saves time and reduces cost of installation. SolarFlex is packaged in a 50-foot continuous coil with a complete range of accessories to ensure a smooth and secure installation.

General

– Easy to separate, without damaging the tubes.
– External copolymer foil protects against UV radiation and mechanical strain.
– Identification mark for flow and return.
– Meets highest requirements for modern solar heating systems.
– Pre-insulated feed and return pipes can be joined easily without special tools.

Product range

Code NA3540-15 SolarFlex 50 foot coil with four 1” union nuts, four segment rings. four flat-sealing washers and two 1” double nipples
Code NA637304 SolarFlex pipe hangers includes four hanger and mounting hardware
Code NA1210-3 SolarFlex connection kit includes four 1” union nuts, four segment rings and four flat-sealing washers

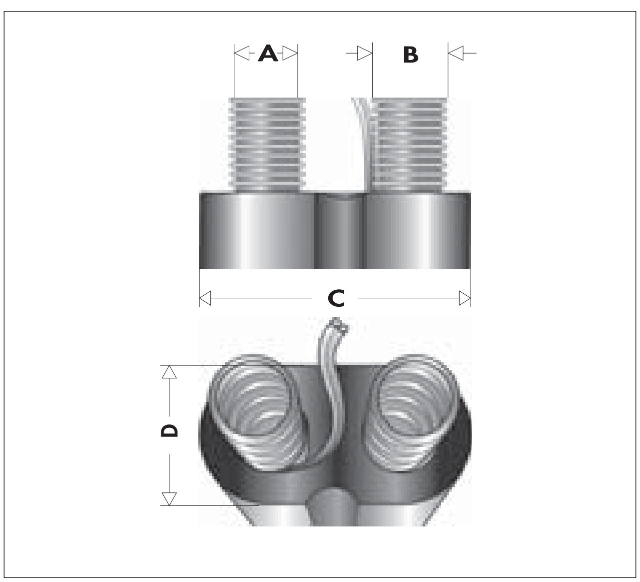
Technical specifications

Materials:
- pipe: two corrugated stainless steel 316L
- insulation: two closed cell elastomer UV resistance EPDM
- outer cover: UV resistant polyolefin copolymer foil

Insulation thickness: 5/8 inch (16mm)
Thermal conductivity at 105ºF (40ºC): R-3.6 (.04W/mK)

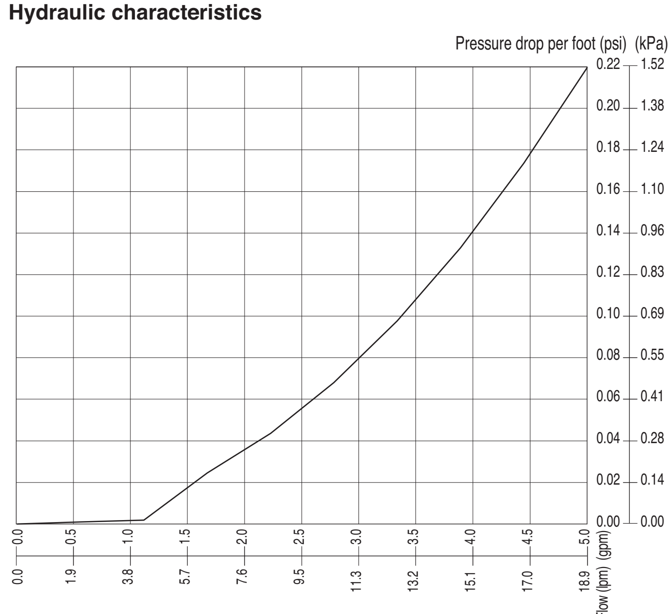
Max. working pressure: 150 psi (10 bar)
Max. fluid temperature: 350ºF (175ºC)
Min. surface temperature: -60ºF (-50ºC)
Length per coil: 50 feet (15m)
Fluid capacity per foot: 0.0346 gallons (0.13 liters)
Min. bending radius: 5 inch (130mm)

Dimensions



Code	A	B	C	D	Weight (lb/f)
NA3540-15	3/4"	15/16"	4"	2 1/8"	0.5

Hydraulic characteristics



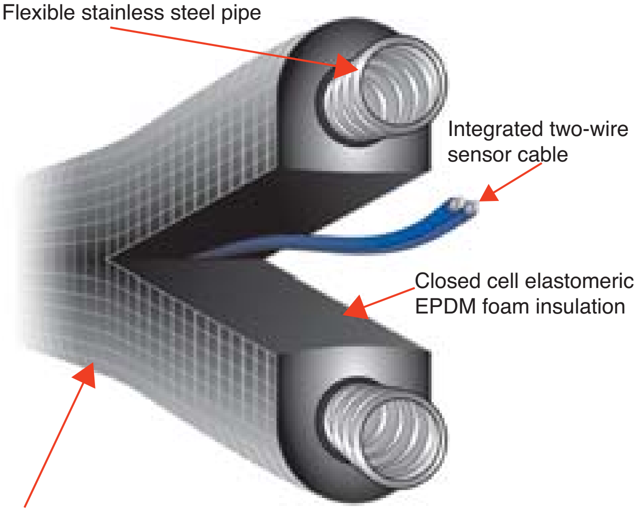
Example: pressure drop at a flow of 3.0 gpm = 0.08 psi x 50 feet of pipe = 4 psi

General

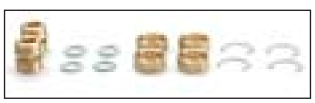
SolarFlex pipe is a flexible, quick installation system to connect solar collectors to the pump station and to the storage tank. The pipe system is easy to install, enabling pipes to be run without using a torch in confined spaces or on the roof. Two closed cell elastomeric foam extrusions of high temperature resistant EPDM are protected against damages by a common outer cover. Flow and return pipes can be easily separated without damaging the insulation.

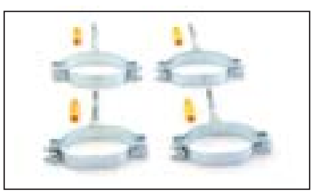
SolarFlex is the way to reduce installation time while ensuring a leak-free installation. SolarFlex's union nut assembly method does not require special tools or time.

Construction details



SolarFlex is packaged in a 50' coil with four 1" union nuts, four flat sealing washers, four segment rings and two each 1" male nipples. Optional pipe hangers keep pipe secure and reduce installation time.



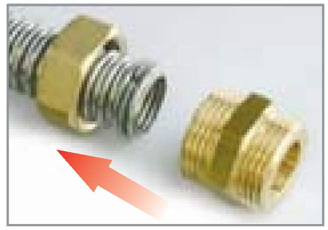


Flow and return pipes are easy to separate without damaging the insulation or sensor cable.

Installation of union nuts

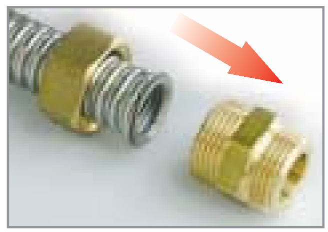
Cut pipe with tubing cutter. Do not use a hack saw.

Slide on 1" union nut and close segment ring around pipe groove.



Connect 1" nipple with 1" union nut without flat-sealing washer.

Tighten 1" nipple to 1" union nut. Forming a flat-sealing surface.



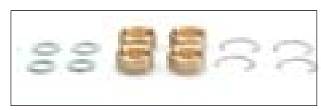
Remove union nipple to inspect flat-sealing surface.

Insert flat-sealing washer and connect to other fittings.

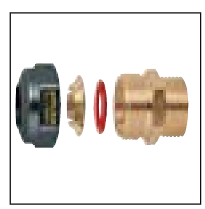
Using cut sections of pipe

Cut the length of pipe required to connect solar collector to the solar pumping stations and attach 1" union nut fittings on each end.
Any remaining short sections of pipe can be used for tank connection or other connections.

Use connection kit **NA1210-3**, which includes four each 1" union nuts, segments rings and sealing washers.



Fitting for connecting to collectors and tanks



Model	Description
NA637204	1" union male to 1" union male nipple
NA10060	1" union male to 3/4" NPT female adaptor
NA10061	1" union male to 3/4" sweat adaptor
NA10062	1" union male to 1" sweat adaptor
NA10064	1" union male to 1" NPT male nipple
254462	1" union male to 22 mm compression
255862	1" union male to 22 mm compression elbow

New North American Headquarters

www.caleffi.us

The Caleffi North American headquarters is located in Milwaukee, WI, centralized in America's heartland. Our home office sits at the eastern edge of Miller Park, home of the Milwaukee Brewers. Completed in November 2007, our 35,000 square foot corporate center is a model of energy efficiency and progressive use of natural resources. Radiant heating comfortably warms the floors, while natural sunlight filters in through skylights which accompany additional energy-saving ambient lighting. Solar heating will supplement the building's existing high-efficiency boilers. At Caleffi, we're energized for our future, creating comfortable environments.

Caleffi North America Inc. - Milwaukee, WI - Tel 414.238.2360 - sales@caleffi.com

CALEFFI Hydronic Solutions

CALEFFI SOLUTIONS MADE IN ITALY