ClimateWell SolarChiller

Design Guidelines for Solar Cooling

ClimateWell

Thank you for choosing ClimateWell SolarChiller!

With Solar Cooling you will feel better…and so will the Environment!

Solar energy day and night
Solar powered heating and cooling both day and night. This is what makes the ClimateWell SolarChiller a unique product and that will enable you to enjoy comfort cooling and heating without compromising the environment. For the first time, a solar powered climate solution meets the requirements both of single family homes and commercial buildings. We made Solar Cooling possible and profitable.

Contribution
Solar Cooling typical monthly savings for a single family home are 100-200 Euros per 100 m² of floor surface. At the same time the owner contributes to a better world by reducing CO_2 emissions by some 5.000 kilos per 100 m² every year.

Independency
With your own energy supply system installed you achieve high Independency of changes in energy prices at the same time as you get immediate savings thanks to the lower energy costs.

Some 25% of the world's CO_2 emissions come from heating and cooling of buildings. With ClimateWell this can now be done using everyone's own energy source. The Sun.

Per Olofsson

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CEO ClimateWell AB

Legal Notes

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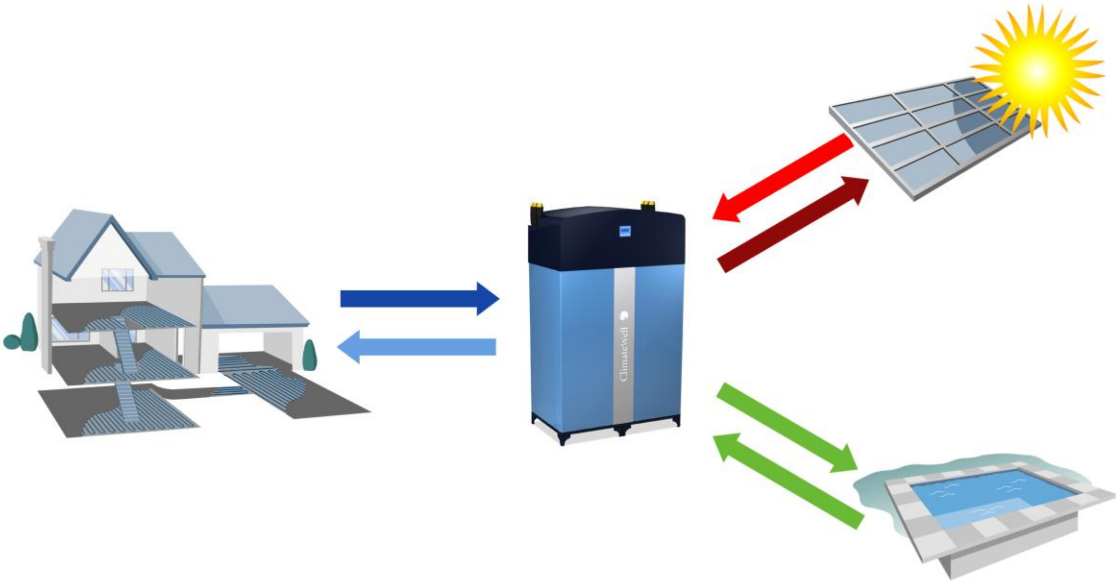


Introduction

This document has been developed to be used as a guideline for designing Solar Cooling installation together with ClimateWell's licensed partners. The document includes key components and component configurations that are crucial for well functioning and reliable Solar Cooling installations. Due to the fact that real projects might deviate more or less from the standard configurations described in the following chapters, it is important to treat this document as a platform for continuous mutual communication between ClimateWell and its partner in the design of specific Solar Cooling projects. More information about the installation and management of a ClimateWell SolarChiller can be found in the ClimateWell User Manual, Installation Manual, Hardware Manual, and Software Manual.

Heat Source System

Introduction

The heat source is the driving force in a Solar Cooling installation. The ClimateWell Solar Cooling products use a single effect triple state absorption cycle working with fluid driving temperatures in the range of 85-110˚C. High regeneration temperatures will increase the vapour flow and hence the charging velocity, but it may not always increase the efficiency of the entire cycle. To find out the optimal driving temperatures and powers for a specific system please use the ClimateWell Solar Cooling simulation tool or ask for a detailed transient simulation from the ClimateWell Customer Support department. A pressure drop diagram for the heat source circuit can be found in Figure 1.

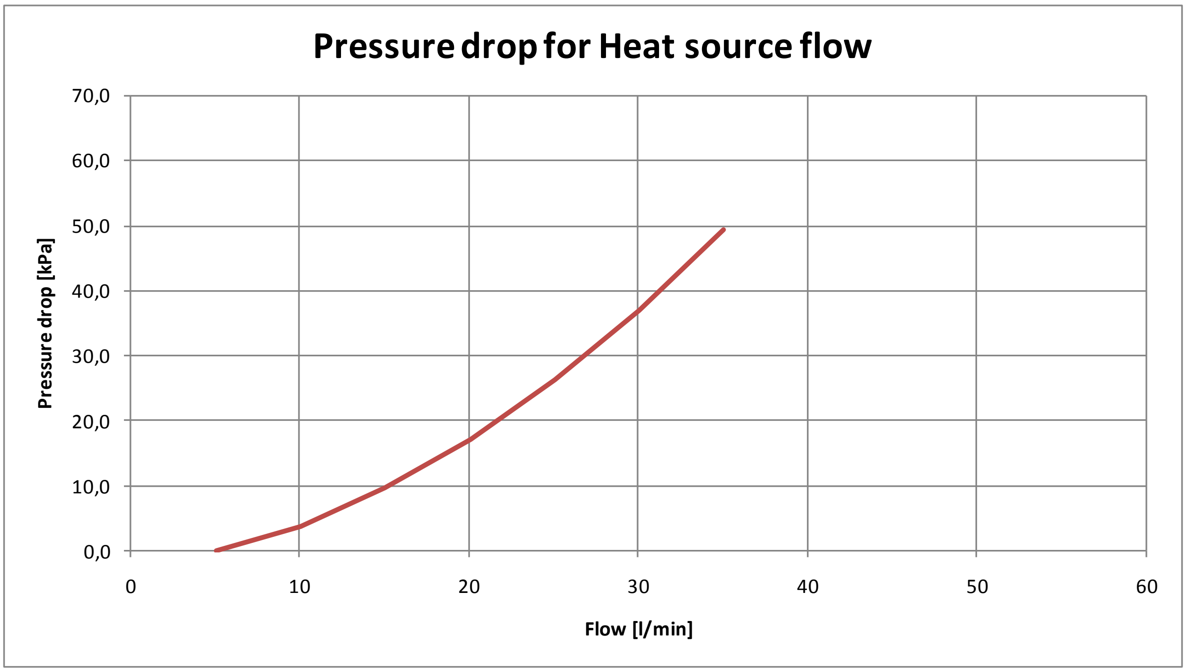


Figure 1: *Pressure drop as a function of the heat source flow for ClimateWell SolarChiller.*

Solar Collectors

Use only certified highly efficient solar collectors with selective absorber plates. Both flat plate and evacuated tube collectors can be used although evacuated tubes generally offer higher efficiencies for high temperature ranges. There are a few aspects besides the thermal performance of the collector that have to be taken into consideration for adequate performance and robustness. The most important ones are the pressure drop through the collector and the stagnation behaviour, and both have to do with the internal collector hydraulics. For flat plate collectors there are three main internal hydraulic configurations seen in Figure 2 and for evacuated tubes there are two different types; direct flow and heat pipes.

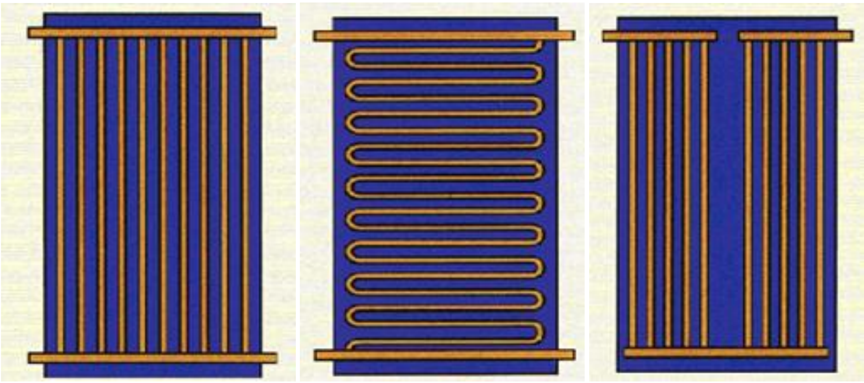


Figure 2: *Internal collector hydraulics for flat plate collectors. From the left: simple harp, double meander and double harp.*

Simple Harp
The simple harp collector is a high specific flow collector with good emptying behaviour in case of stagnation and low pressure drop. Due to the low pressure drop a very high specific flow is necessary to balance the flow through each collector and therefore the simple harp collector must be connected in series as shown in Figure 6.

Double Meander
The double meander collector is a low specific flow collector with good emptying behaviour in case of stagnation and low pressure drop if connected in parallel. Due to the higher pressure drop compared to simple harp the meander collector is easier to balance hydraulically and can therefore be connected in long arrays in parallel as shown in Figure 5.

Double Harp
The double harp collector is a low specific flow collector with poor emptying behaviour in case of stagnation and high pressure drop if connected in series. This collector has only one inlet and one outlet and can there for only be connected in series. In order not to have too high pressure drops in the collector array a low total flow must be used which results in a high deltaT over the collector field. A high deltaT is acceptable in domestic hot water installation where a highly stratified storage buffer is desired, but is not recommended in a solar cooling application. For these reasons the double harp collector is not recommended by ClimateWell.

Direct Flow Evacuated Tube
The direct flow evacuated tube collector is a high specific flow collector with poor emptying behaviour when installed with the tubes vertically, and low pressure drop. If installed vertically, during stagnation some of the collector fluid will be trapped inside the collector, similarly to the double harp collector, and due to the extremely low thermal losses and hence very high stagnation temperatures in the evacuated tubes, the glycol might degrade. For this reason the direct flow evacuated tube collector is only recommended by ClimateWell if installed horizontally according to the right picture in Figure 3.

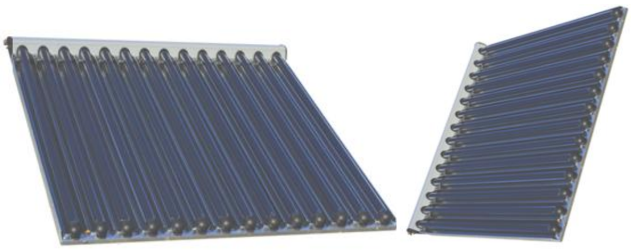


Figure 3: *Direct flow evacuated tube installed vertically to the left and horizontally to the right.*

Heat Pipe Evacuated Tube
The heat pipe evacuated tube collector is a high specific flow collector with good emptying behaviour in case of stagnation and low pressure drop. Some heat pipe manufacturers even offer heat pipes with a maximum temperature in order to minimize the effects of stagnation. Due to the low pressure drop many collectors can be installed in series as illustrated in Figure 4.

The number of collector panels in each bank should be according to the panel manufacturer's guidelines.

- Design the individual collector banks so that the temperature difference between inlet and outlet at maximum irradiation is acceptable for the different demands. If all the power should be absorbed by the ClimateWell unit/units then the temperature difference should be no more than 15˚C. In case of higher complexity such as installations with high domestic hot water demand please consult with ClimateWell technical department for help on designing the individual flows.
- Install reversed return hydraulics to ensure the same pressure drop in each bank in the collector array regardless of the flow. This is a requisite for using variable flow in the collector loop.
- Install temperature sensors in each collector bank inlet and outlet. These sensors are used to make sure that the same flow is passing each collector bank in the array. Manual bypass flow meters can also be used in each bank.
- Use an immersed solar collector temperature sensor on any bank in the collector array, and a second sensor close to ClimateWell unit outlet for pump control. Make sure that the sensor is measuring the collector temperature and not the flow temperature in the pipes. A temperature sensor attached to the pipe cannot be used for pump control since the sensor must be able to measure the absorber plate temperature even when the solar pump is off.
- The specific collector flow rate (the flow rate through one collector) should be according to manufacturer specifications and the hydraulic configuration should be designed to match the flow demanded by the Climatewell units. Generally the total solar field flow is in the range of 20 to 50 l/hr per m^2 aperture area depending on the type of solar collector. Figure 4 – Figure 6 illustrate some examples on possible hydraulic configurations for different solar collectors.
- Install shut-off valves at the inlet and outlet of each collector bank in accordance with Figure 4 - Figure 6. This is important for start up and maintenance reasons.
- Install a flush out connection at the extremes of both the inlet and outlet of the collector field according to Figure 4 - Figure 6. These connections can be used for purging the system as well.
- Install safety valves for each collector array on the inside of the shut-off valves as shown in Figure 4 - Figure 6.

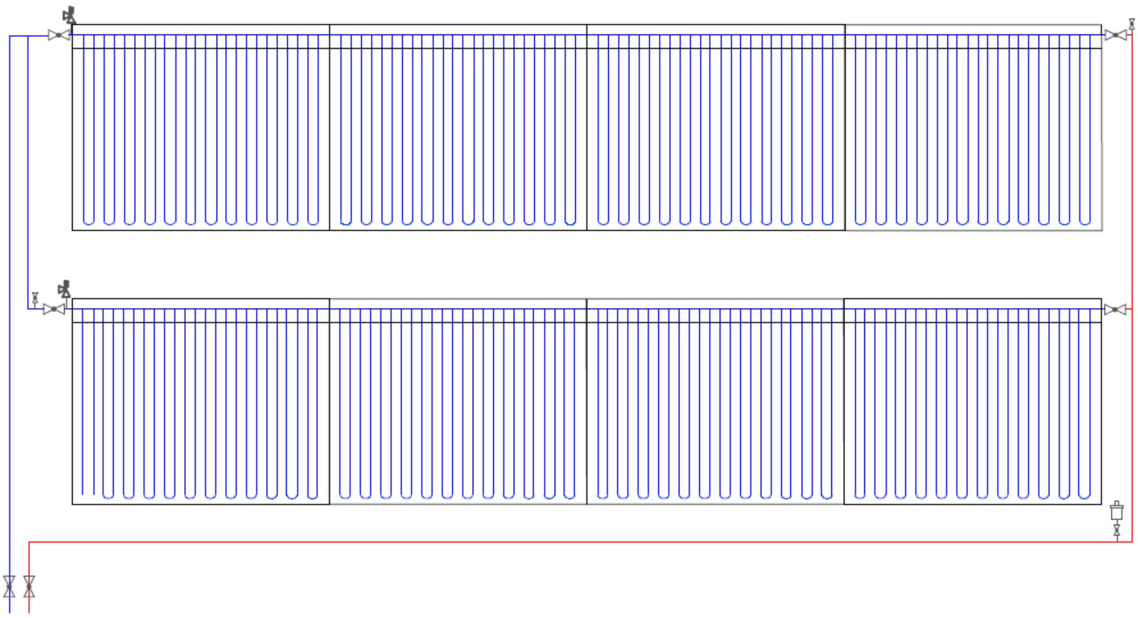


Figure 4: *Heat pipe evacuated tube hydraulics with two parallel banks with each four collectors connected in series. For direct flow evacuated tube collectors the tubes must be installed horizontally.*

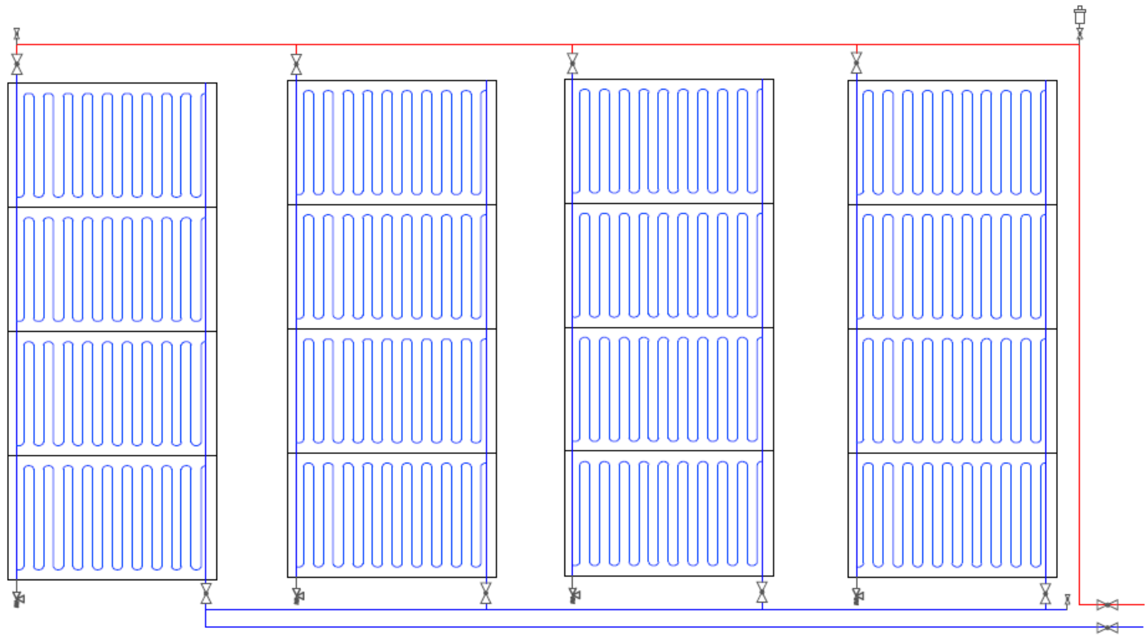


Figure 5: *Double meander hydraulics with four parallel banks with each four collectors also connected in parallel. Both direct flow and heat pipe evacuated tubes can be connected in a similar way, with the difference that the collectors in each bank are internally connected in series instead of in parallel.*

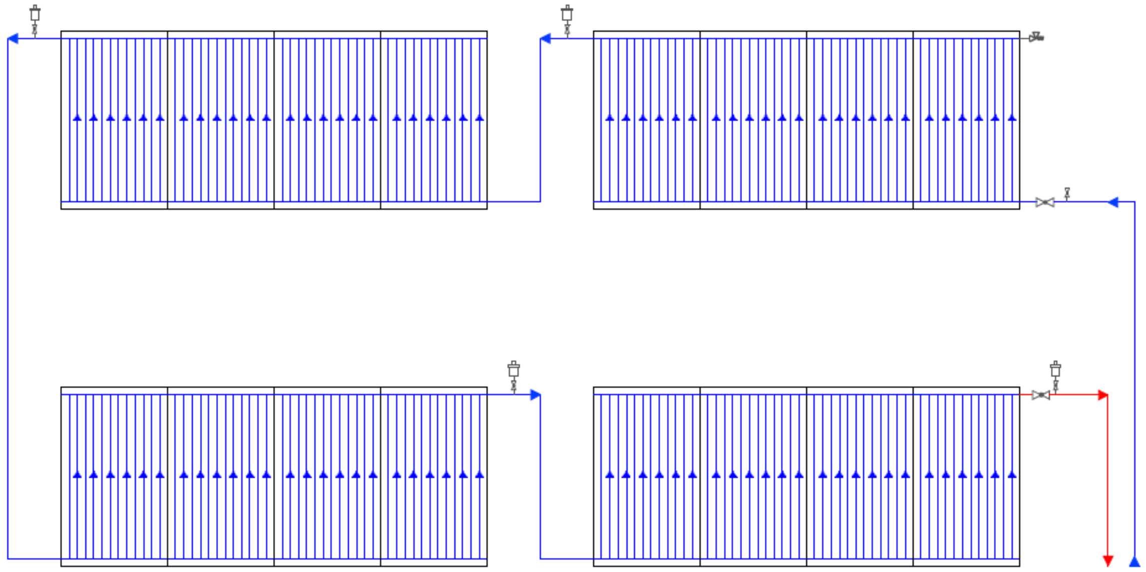


__Figure 6:__ Simple harp hydraulics with four banks connected in series with each four collectors connected in parallel. Simple harp is a high flow solar collector and it is recommended to have at least four collectors in series in order to obtain sufficient flow through each collector. More than four collectors in parallel in one bank are not recommended because the flow is then unevenly distributed.

Collector Fluid

Use only reversibly evaporisable heat transfer fluid based on propylene glycol and non-toxic corrosion inhibitors with pH buffering capacity for utilization in solar heating installations. The fluid should be able to withstand at least 170˚C without being altered. Since water quality depends greatly on location ClimateWell only recommends pre-mixed products.

Stagnation Behaviour

- Use a safety algorithm for the solar pump that automatically shuts off the solar pump if the collector temperature exceeds 130˚C.
- The solar pump must under no circumstances be turned on during collector stagnation.
- Install pipe work for both flow and return with a continuous upward slope towards the solar field. This will give a slower and more controlled vapour transport during stagnation.
- Make sure that the vapour always has somewhere to expand. There must be an unhindered path from the solar collectors to the expansion vessel in order to avoid pressure peaks.

Pipes

- Design pipe dimensions to have 0.5-1.5 m/s flow velocity, but never more than 20 mm/m (mm pressure head per length meter pipe) pressure drop.
- Use only copper or stainless steel pipe material in any high temperature circuit. Stainless steel offers the most efficient and reliable performance for the collector loop.
- Always follow or exceed local or regional normative when designing the pipe work.

Higher flow velocities than 1.5 m/s will give unnecessarily high pressure drop in the loop, and lower velocities than 0.5 m/s will make it impossible for air bubbles to reach the purge unit while increasing the thermal losses.
In order to avoid confusion when connecting the pipes the flow and return can have different colours, see Figure 19.

Losses

Insulation should be of a sufficient thickness and standard in order to limit heat loss from the pipes to and from the collector field. **Less than 0.15 W/K** per length meter pipe is recommended.

- The insulation must be resistant to weathering and meet or exceed the requirements of standards such as EN 483 or EN 513.

Collector inclination, orientation and shading affect the performance of the solar cooling installation to varying degrees.

- Optimum inclination is usually close to, or slightly lower, the latitude of the location.
- Always try to orient the solar field towards the equator where efficiency will be highest. Small deviations from the optimum azimuth will have limited or no adverse affect on performance.
- Never install a solar field close to large obstacles that can potentially shade the collectors. If mountains, trees or other objects are located in a way that may shorten the daily operation time during certain periods of the year this must be taken into account during the design phase of the installation.

Distribution System

Introduction

The distribution system of the building connects to the evaporators of the ClimateWell units and is the driving force in the absorption process just as the heat source is the driving force during the regeneration of the absorbent. Since water is the refrigerant in the absorption cycle no sub-zero temperatures are possible. The Climatewell units are designed to work with high temperature systems ranging from 10-16˚C on the outlet from the ClimateWell unit and performance rapidly decreases below this range. Since the products loose efficiency at lower temperatures it is not recommended to use a Solar Cooling installation for dehumidification purposes. For very humid climates a backup system is highly recommended.

A pressure drop diagram for the distribution circuit can be found in Figure 7.

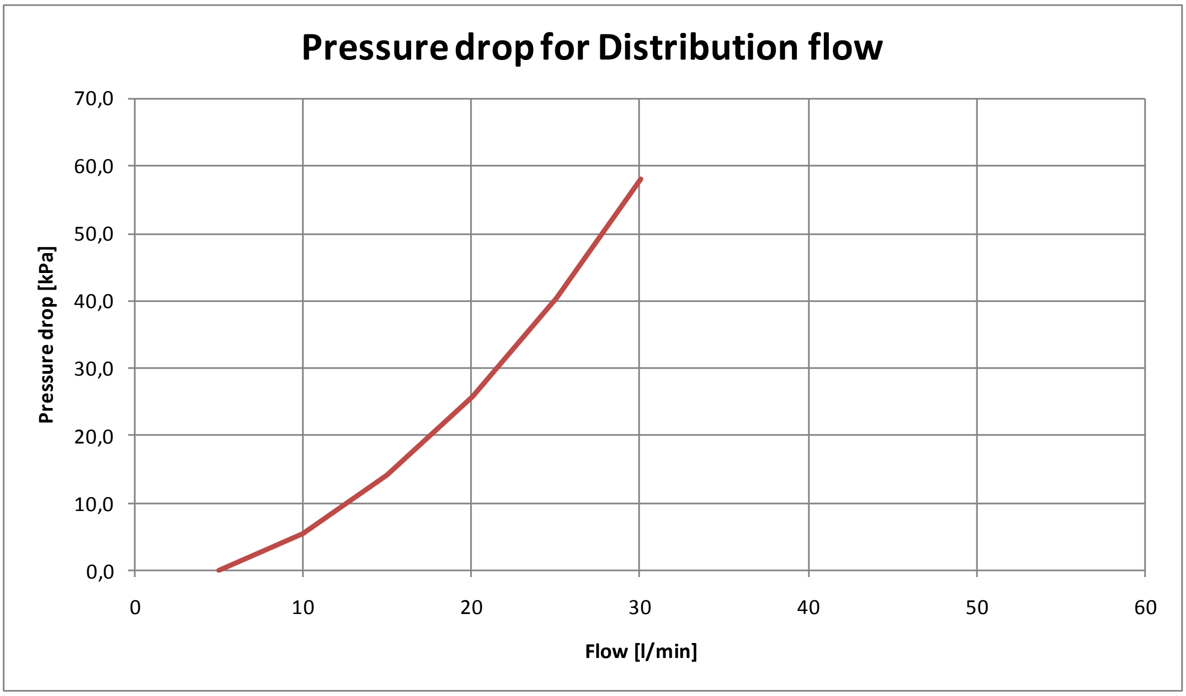


***Figure 7:** Pressure drop as a function of the distribution flow for ClimateWell SolarChiller..*

Air Handling Unit

An air handling unit (AHU) can be connected to a conventional ventilation ducting system with inlet air diffusers in each area, or to a VAV (Variable Air Volume) system.

An AHU in combination with ClimateWell and a backup system with a conventional chiller must always have 2 separate cooling coils since the 2 systems operate at different chilled water temperature levels. In order to maintain a high COP on the conventional chiller and a good performance from the ClimateWell units, these two circuits should never be mixed. For each coil inside the AHU a separate 3-way valve control the air supply temperature via the BMS-system (Building Monitoring System) or a conventional control system. Typical components in an AHU are listed below starting at the air inlet and going along the air flow.

- Sand trap (DIN std EN779).
- Mixing section for inlet and return air.
- Filter (DIN std EN779).
- Pre-cooling coil for ClimateWell units (12-17˚C). Pressure drop <30 kPa on water side and <100 Pa on air side.
- Cooling coil for conventional chiller/boiler.
- Damper section
- Fan section with low SFP-value (EN 13779 SFP: Specific Fan Power, W/m³/s).
- Silencer

The air flow should be designed for maximum 2.5 m/s air velocity over the cooling coil sections. If not, condense drop eliminators after the coil are necessary. The pressure drop over the coils should be as low as possible to avoid unnecessarily large circulating pumps/fans. Use air fans with as low SPV-values (W/m³/s) as possible. Table 1 illustrated an example of an AHU specification.

Table 1: *Example of design data for an air handling unit.*

Design data: AHU1					
Supply air; m3/sec	3.80		Chilled water temp./KB2	+7/+12˚C
Ext static pressure (Pa)	350		Coil: Air inlet temp./RH	+27˚C/50%
Return air; m3/sec	3.50		Pre-filter	MERV 6
Ext static pressure (Pa)	225		Filter	MERV 13
Coil 1:	Al/Copper		Heat Exchanger/Plate Cross Air	None
Capacity (kW)	60		Exhaust air; m3/sec	0.4
Chilled water temp./KB1	+12/+17˚C		Frequency control	Yes/no
Coil: Air inlet temp./RH	+27/50%		Max sound level outlet before silencer	90 dBA
Coil 2:	Al/Copper		Max sound level outlet after silencer	55 dBA
Capacity (kW)	120			

Hollow Core Slabs

The hollow core slab system offers one of the most energy efficient HVAC solutions available on the market while providing top rated comfort levels. This is possible by adding a massive thermal storage to the air distribution; the building itself.

The hollow core slab system can be combined with all types of Air-Conditioning/Air Handling units (AHU) units. From the AHU-unit, generally placed on the roof, supply air ducts run in vertical shafts down to each floor inside the building and then to horizontal ducts placed in central corridors usually within false ceilings. Small branch ducts feed air into each slab, and the air then enters a room via diffusers fixed to the outlet of the slab. Diffusers are normally located close to external walls, or evenly spread over the ceiling in the office landscape. The exhaust air is normally transferred into the central corridor plenum and is returned to the AHU-unit in a conventional way.

The main distribution ductwork in the corridor is similar in construction to that found in conventional systems. The main difference with this system is that every individual structural hollow core slab is supplied with a small quantity of air from the main supply duct.

The system is different from conventional technologies because it is integrated with the heavy structure of the building. The last part of the ductwork system for the supply air consists of hollow core concrete slabs instead of traditional steel ducts.

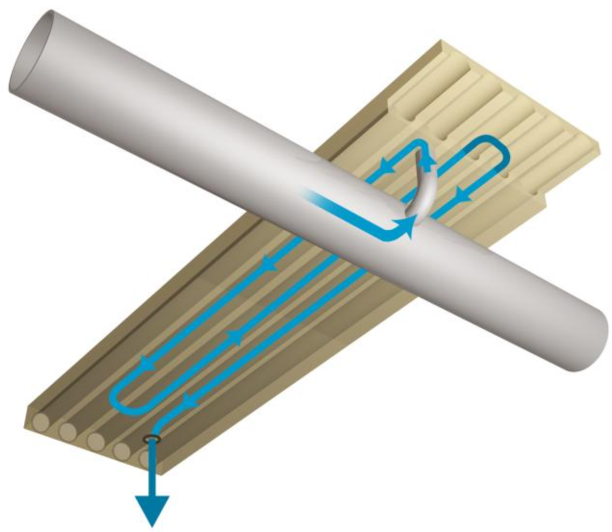


Figure 8: *Air flow inside the hollow core slabs.*

The system uses the thermal storage capacity of the structural mass in the building to regulate the internal temperatures. The effectiveness of the building's thermal mass is enhanced by passing supply air through the slab before it enters the room. The slabs work as heat exchangers between the supply air and the rooms, see Figure 8.

The floor/ceiling slabs serve many purposes: Besides from being the structural floor it also conveys fresh air into the building while serving as an energy store.

The slabs are incorporated into the building and the main supply duct would normally be situated in the corridor. No ducts and therefore no false ceilings are required in individual rooms. This allows total freedom for the interior designer to locate, or re-locate in the future, the internal wall partitions.

Chilled Beam System

In application with an AHU in areas/rooms with higher heat load, like meetings or conference rooms a chilled beam system is highly recommended.

Chilled beams are very effective and easy to install and connect to the Climatewell chilled water circuit, since the chilled beams require higher water temperatures in order to avoid condensation inside the units.

The base load into these areas is supplied by the AHU/Ventilation system and the top load is supplied by the chilled beams, often in combination with air supply inside the chilled beams.

The chilled beams are controlled by a separate room sensor/control opening the valve for the extra chilled water into the coil for maintaining the room temperature under high load conditions. Some chilled beams are designed to be a part of a suspended ceiling and are very easy to install retrofit. No noise from the chilled beams themselves is another great advantage.

Radiant Systems

Radiant systems are typically designed to work at temperatures close to the indoor air temperatures. This is possible because of the large contact area between the heating/cooling medium and the radiant panel and between the radiant panel and the indoor air. These systems are thus very efficient, since they require less exergy than other systems to maintain conditions of comfort. The major drawback of these systems is that they will only cover sensible cooling loads.

In floor systems, in winter, the mortar absorbs the heat given off by the pipes and conveys it to the upper flooring, which, in turn, conveys this energy towards the walls and ceiling of the room by means of radiation and, to a lesser degree, natural convection. In summer, on the other hand, the flooring absorbs the heat from the walls and ceiling by radiation and partly by convection. Ceiling systems are solutions based on circulation of hot/cold water through panels installed in the ceilings.

Radiant systems adjust very well to the optimal projection of human body heat, by means of radiation, convection, transmission and evaporation. The temperature that you feel is more or less the average temperature between the radiant temperature and the dry bulb temperature, illustrated in the picture below.

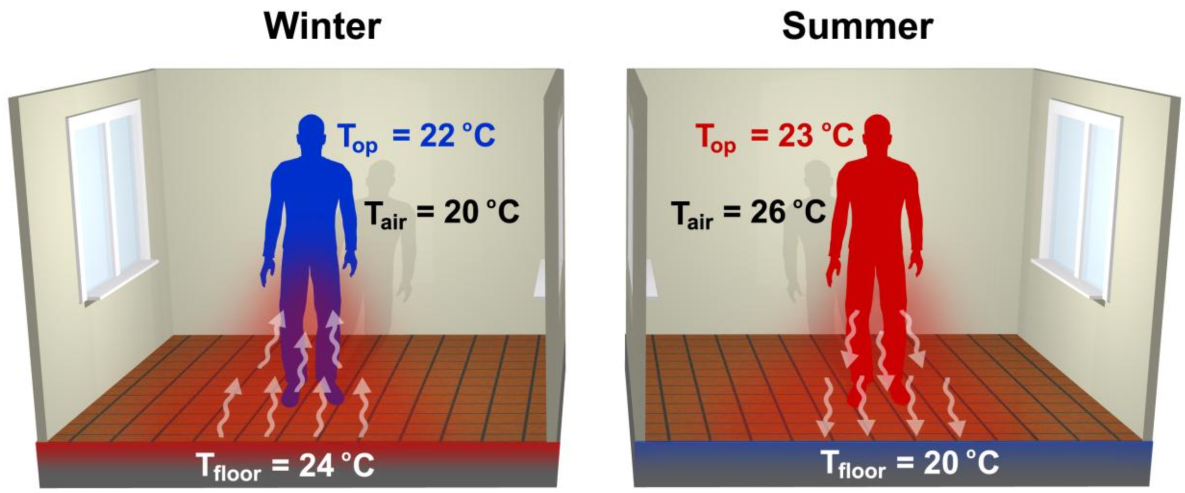


Figure 9: *The temperature perceived by a person (operational temperature) is a function of the ambient air temperature and the radiant temperature from all surfaces surrounding the person. This means that the ambient air temperature can be lower in winter and higher in summer with the same level of comfort compared to a system based on convection resulting in significant energy savings.*

In addition, they take advantage of the structural systems of the building (floor, ceiling, walls) as elements that accumulate energy (thermal mass), and this cushion temperature variations and lower peak demands.

The active contact area of the air volume under temperature control is the entire floor / ceiling. This means that thermal exchange is uniform throughout the surface, making the movement of air by convection imperceptible.

The distribution circuits depart from the supply and return manifolds. From there, the circuits are hydraulically balanced and the circulation of the water projected is regulated in accordance with the thermal needs of each space. The manifolds are placed centrally with respect to the areas to which they provide service. At least one electronic valve is necessary for every thermostat controlled space, and each manifold has a maximum of 12 circuits. For maximum comfort it is recommended to use one thermostat for each space (bedroom, kitchen, etc.).

For optimum temperature control the advisable circuit design is either double coil or spiral. The supply and return pipes should always be contiguous so that the warmer pipe is always next to the colder pipe. This design ensures homogenised thermal distribution and increased comfort.

For heating, a separation of 20 cm between each individual pipe is considered normal, and for air-conditioning, a separation of 15 cm is necessary (except in bathrooms, with a 10 cm separation). The type of distribution pipe and the separation between pipes should remain constant throughout the entire installation.

Parts 1-4 of UNE EN 1264 specify the design and installation requirements of radiant floor heating systems. Nonetheless, this standard does not cover the design of floor-based cooling systems.

UNE EN 1264-2 establishes a characteristic base curve that determines the balance between thermal flow density (q) in W/m2 and the mean temperature of the floor surface in ºC. It is applicable to all types of radiant systems. The proportion between these is established as follows:

Hot floor / Cold ceiling: $q= 8.92 \times (T_{floor/ceiling} - T_{operative})^{1.1}$
Cold floor: q= 7 x (Tsurface – Toperative)
Hot ceiling: q= 6 x (Tsurface– Toperative)

Radiant floors are considered suitable when the heating load is less than 100W/m^2, and the cooling floor when the load is less than 40W/m^2.
For the floor, the minimum temperature recommended is 18 ºC, although it will always be necessary to take the dew point of the air into account so as not to generate condensation. The theoretical minimum ceiling temperature is 8ºC, although the real limit will be the dew point of the air.

Heat Rejection System

Introduction

A solar cooling system must always have a heat rejection system where the heat from the solar collectors and from the building is dumped. The heat rejection system should be designed in such a way that the return to the Climatewell units does not exceed 35˚C for the design power of the circuit. Generally the performance of the Solar Cooling installation improves the lower the heat rejection temperature. Similarly an under-dimensioned heat rejection system is likely to undermine the entire installation. For these reasons high efforts should be put into the design of the heat rejection system. A pressure drop diagram for the heat rejection circuit can be found in Figure 10.

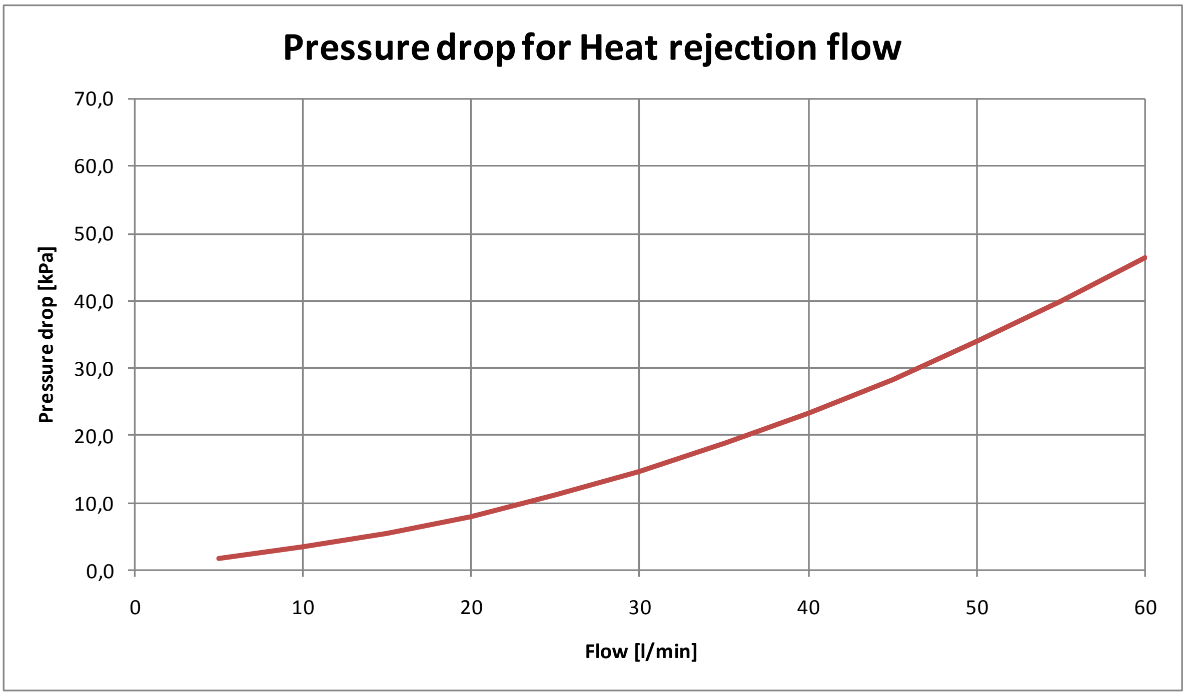


Figure 10: *Pressure drop as a function of the heat rejection flow for ClimateWell SolarChiller.*

Two or more heat rejection system can be used in a single installation and they can be connected either in series or in parallel. Figure 11 and Figure 12 illustrates how different rejection systems can be coupled together.

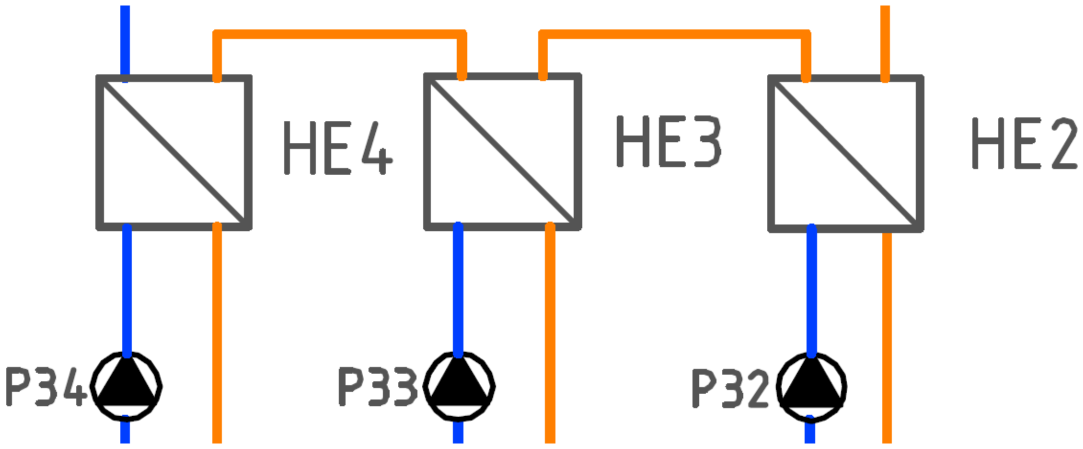


Figure 11: Connection in series for three different heat rejection systems. Preheating of DHW (HE2) has always highest priority and is therefore placed first in the flow direction. A wet cooling tower (HE4) has always lowest priority and is therefore placed last.

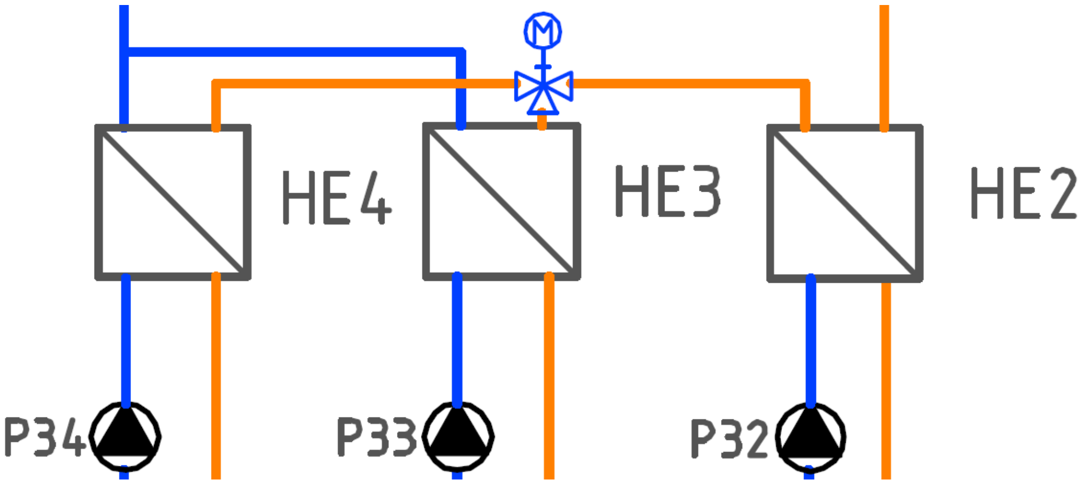


Figure 12: Connection in parallel for two rejection systems (HE3 and HE 4) connected in series with a third system (HE2) with highest priority.

Swimming Pool

A swimming pool can be the only heat rejection system in the solar cooling installation, but can also be used in combination with other solutions if size is not sufficient or if the pool is strictly temperature regulated. Use connection in parallel with secondary heat rejection system if the pool heating season is during a short period of the year. If not, connection in series can be used to simplify control logic. If preheating of domestic hot water is used, connection in series is always recommended. It is important to use a pump, on the pool side of the heat exchanger that can work at ambient pressure. Normal circulation pumps need a higher incoming pressure and will not work well in a non pressurized circuit.

It is also important to choose a heat exchanger that will withstand the corrosive environment present in pool applications. The material used in the heat exchanger must be chosen depending on what chemicals are used in the pool water. A heat exchanger that can withstand chlorinated water might not withstand salt treated water or seawater. Figure 13 shows an example of a shell and tube heat exchanger especially designed for pool applications. It can handle both chlorine water and seawater and has very low pressure drop.

Figure 13: *A pool heat exchanger from Bowman. The heat exchanger has plastic fittings on the pool side that can withstand maximum 100˚C.*

Wet Cooling Tower

A wet cooling tower is the most conventional way of rejecting heat in solar cooling applications. The evaporative cooling allows the tower to deliver temperatures below the ambient dry bulb temperature which is a necessity for solar cooling installations in warmer climates. When dimensioning the cooling tower, maximum and average wet bulb temperatures for the location must be taken into account.

The maintenance necessary for a cooling tower consists mainly of hygienic maintenance since mechanical maintenance is minimal. Sanitary standards should follow or exceed normative such as RD865/03. Some cooling tower manufacturers recommend a slow dissolution solid treatment which is a solid cleaning tablet that works both as biocide and corrosion inhibiter during a period of roughly six months.

Another very important parameter to determine in the design of the cooling tower is the number of concentration cycles that can be used. The concentration of minerals such as Ca and Mg increases as the water evaporates and in order to avoid deposition and accumulation of minerals inside the cooling tower a certain amount of water must continuously be replaced with new water in addition to the water lost through evaporation. The quality of the water at the location is what will decide the number of concentration cycles, where very pure water can be concentrated many times before deposition becomes a danger, and water with high concentration of minerals must be replaced more often.

For guidelines on maintenance and dimensioning of fan speed, sump volume and number of concentration cycles, contact the cooling tower manufacturer.

Preheating of DHW

Preheating of DHW is the most favourable of all heat rejection systems since the exergy levels are used very efficiently. First the heat is used for producing cooling and later the same energy can heat up the tap water. The disadvantage with this rejection system is that it is dependent on the tap water consumption and can therefore never be used as the only system for heat rejection. It can neither be used as the sole source for heating the tap water because maximum available temperatures are below sanitary requirements. The preheating of tap water should be done in a separate tank in order to allow for good stratification. See the chapter on DHW preparation for further information.

Domestic Hot Water System

Thermal Storage

The use of open buffer tank is recommended in installations with both DHW and heating demand, especially if high hygienic standards are required. For smaller installations, or if no heating is required from the solar installation, domestic hot water tanks can be readily used.

DHW Preparation

There are basically two different schools when it comes to domestic hot water preparation. Either hot water for consumption is prepared and stored in DHW tanks before use, or the water is heated up instantaneously at demand. The main advantage with the first solution is that high peak demands can be covered with small capacities on heat exchangers, but with the side effect that storing warm water (<53˚C) may create hygienic problems. The latter solution gives high hygienic standards since cold water is heated instantaneously, but requires that heat exchangers are dimensioned for the peak power demand. Figure 14 and Figure 15 illustrate how the two solutions can be combined with solar heating and preheating.

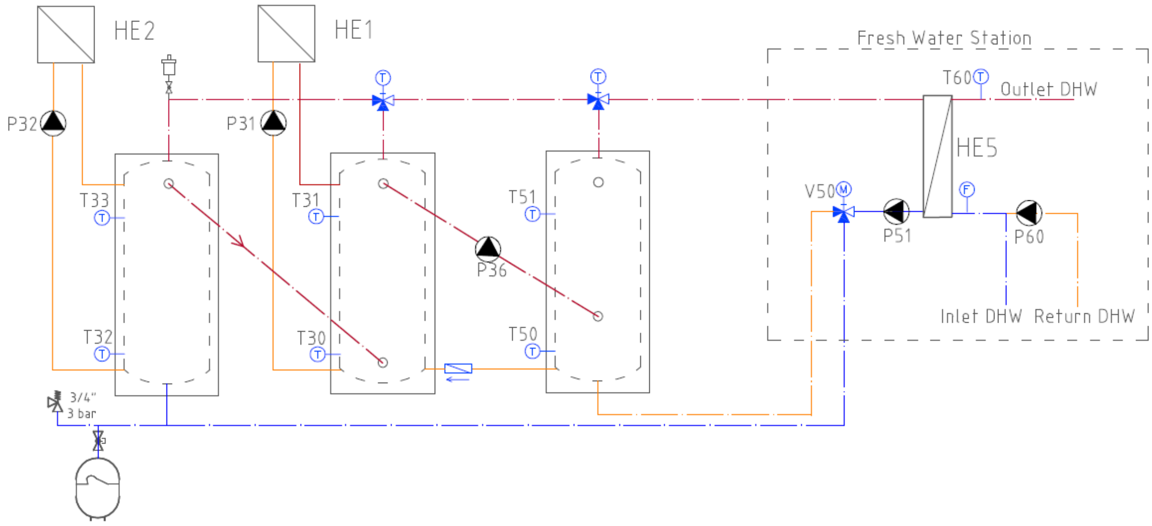


Figure 14: *Domestic hot water solutions with open buffer tanks and instantaneous hot water preparation. The three tanks are starting left: preheating tank (tank heated by the heat rejection circuit of the ClimateWell units) (20-40˚C), solar tank (40-70˚C) and boiler tank (60˚C).*

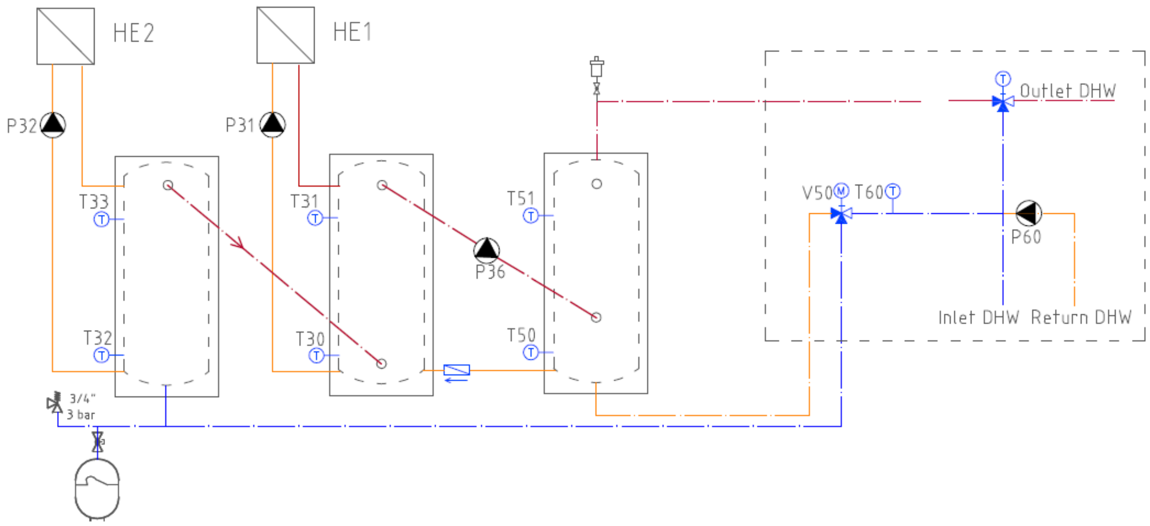


Figure 15: *Domestic hot water solutions with DHW tanks. The three tanks are starting left: preheating tank (tank heated by the heat rejection circuit of the ClimateWell units) (20-40˚C), solar tank (40-70˚C) and boiler tank (60˚C). Make sure that the chosen solution follows local normative.*

For smaller installations with no preheating a single tank can be sufficient.

Hydraulic Design

All components connected to the collector loop must have a high temperature classification.

Solar Pump Station

The solar pump station is the connection between the solar collectors and the rest of the components in the installation. There are standard pump stations for small to medium size installations existing on the market that come pre-installed and leak tested with all the necessary safety equipments. An example of a pump station is illustrated in Figure 16 and a list of the necessary components can be seen below. For larger installations preassembled pump stations are not common, and the components are normally assembled and installed on site.

1. Variable speed circulation pump
2. Safety relief valve
3. Filling/drain valve
4. Pressure gauge
5. Flow meter
6. Air trap and vent
7. Flow temperature gauge
8. Return temperature gauge
9. Insulation shell
10. Shut-off and check valves
11. Expansion vessel connection

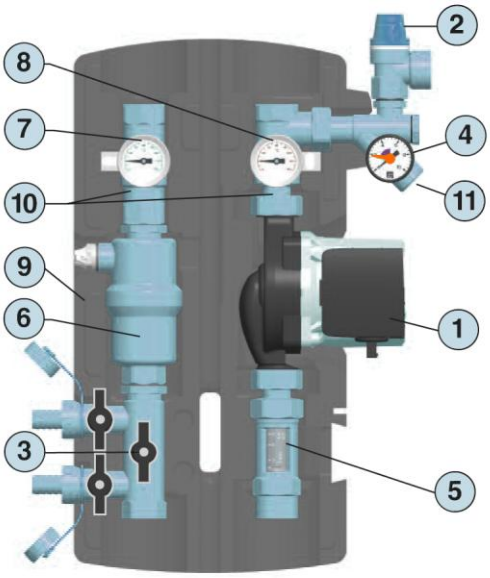


Figure 16: *Example of a solar pump station designed for small to medium size solar installations.*

In Figure 17 and Figure 18 some examples of pump station components available on the market is shown.

Figure 17: *Straight flow regulator and flow meter, to the left combined with two valves to fill and drain the installation.*

Figure 18: *Combined temperature gauge, shut-off valve and non return valve for pumps stations.*

Expansion Vessel

Make sure that the expansion vessel pre-pressure and the final system filling pressure are measured with a digital instrument. The expansion vessel should be of high temperature rating for solar applications and be installed before the solar pumps. In small installations it can be installed after the non return valve on the flow pipe to the solar collector.

- Design expansion vessel in accordance with VDI6002 or local standards. ClimateWell can provide support on expansion tank dimensioning according to VDI6002.
- A service valve should be installed between the expansion vessel and the safety valves equipped with a lockable handle
- The expansion vessel should be placed below the pump station in order to stop hot water rising in the pipes from reaching the vessel.

Failure to correctly dimension the size and the pre-pressure of the expansion vessel and the filling pressure of the installation can lead to air leaking into the system during cold nights or to glycol degradation during high thermal stress.

Cooling Vessel

A cooling vessel may be required depending on the hydraulic design of the system. If the location of the pump is sufficiently distant from the collector field and during a standstill event the collector field can expand equally along both the flow and return pipes without vapour reaching the pump then a cooling vessel is not required. However, if a check valve is required before the pump for protection meaning that the collector field is only able to expand along the flow pipes a cooling vessel may be required. In this case if the fluid volume of the pipes between the collector field outlet and the expansion vessel inlet is less than the volume to be held by the expansion vessel then a cooling vessel must be added to protect the expansion vessel. The volume of the cooling vessel must be such that when added to the fluid volume of the pipes between the collector field outlet and the expansion vessel inlet the total volume exceeds the volume to be held by the expansion vessel.
Which method to use must be decided on a case to case basis depending on distance to solar field and stagnation behaviour of the collectors used.

Deairation

- Install at least one air purge unit (APU) per circuit with a residence volume (2-5 pipe diameters in length) for air in a T-section or elbow.

An automatic purge valve can be used, but controlled by a manual valve that should always be closed during normal operation. Increase the pipe size in that section to lower the flow velocity. The purge system can be placed close to the pump station for easy maintenance. In larger installations several APU units are recommended. Figure 19 illustrates how an APU should look like.

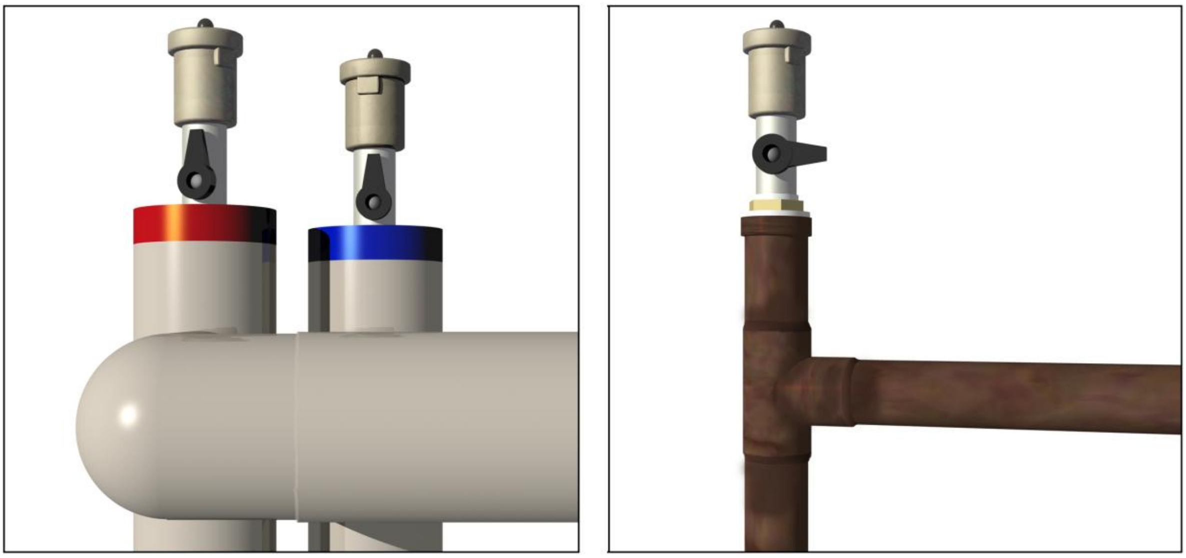


Figure 19: *Example of an APU consisting of an automatic purge valve, a manual valve and a residence volume for air. Different colours are used for flow and return.*

Strainer

- It is recommended to install a strainer of 1-1.5 mm mesh before the pump with service valves on each side.

The strainer is a filter with large mesh that will collect dirt in the circuit. Connections for measuring the pressure over the strainer are recommended to know when it needs to be cleaned or replaced. When installing a strainer it is important that maintenance is really performed and strainer is cleaned or replaced when dirty. Failure to do so may lead to clogging of the system and unrepairable damage to pumps.

Safety Valves

- Double safety valves are recommended for larger installations, separated by a 3-way ball valve for easy maintenance.
- Choose the rated pressure for the safety valve according to the VDI6002 standard. The right pressure will depend on the height of the collector field and the selection of heat transfer fluid.
- If the collector field is very large or far away from the pump station additional safety valves close to the collector field are recommended.
- If there is any risk for vapour reaching the solar pumps during stagnation, a non-return valve must be installed after the solar pumps on the return pipe to the collectors in order to protect the pumps.

A second non return valve can also be used in the flow pipe of the collector to prevent self circulation in this single pipe up to the collector.

Heat Exchangers

- Use flat plate heat exchangers with approximately 3˚C logarithmic temperature difference for the design power of the circuit.
- A maximum of 30 kPa pressure drop over the heat exchanger is recommended. If possible similar flow should be used on both sides of the heat exchanger.

The design power for the different heat exchanges can be obtained using the ClimateWell Solar Cooling dimensioning tool. Typical heat transfer values for a single ClimateWell SolarChiller installation are 20-30 kW for heat rejection and 7-10 kW for distribution.

If the collector field is located far away from the machine room making costs for collector fluid unrealistically high, a flat plate heat exchanger close to the collector field can isolate the primary solar side from the rest of the installation. This will leave the ClimateWell units without any freeze protection and extreme care has to be taken in the design of the installation. Failure to do so may lead to irreparable damage to the ClimateWell units.

Pumps

The electrical efficiency of the system is of highest importance, and fluid pumping is one of the key factors influencing this efficiency. Like most solar installations a Solar Cooling system is often run at partial load (off peak hours). This is illustrated in Figure 20 where it can be seen that a system runs at its full capacity very few hours in a year.

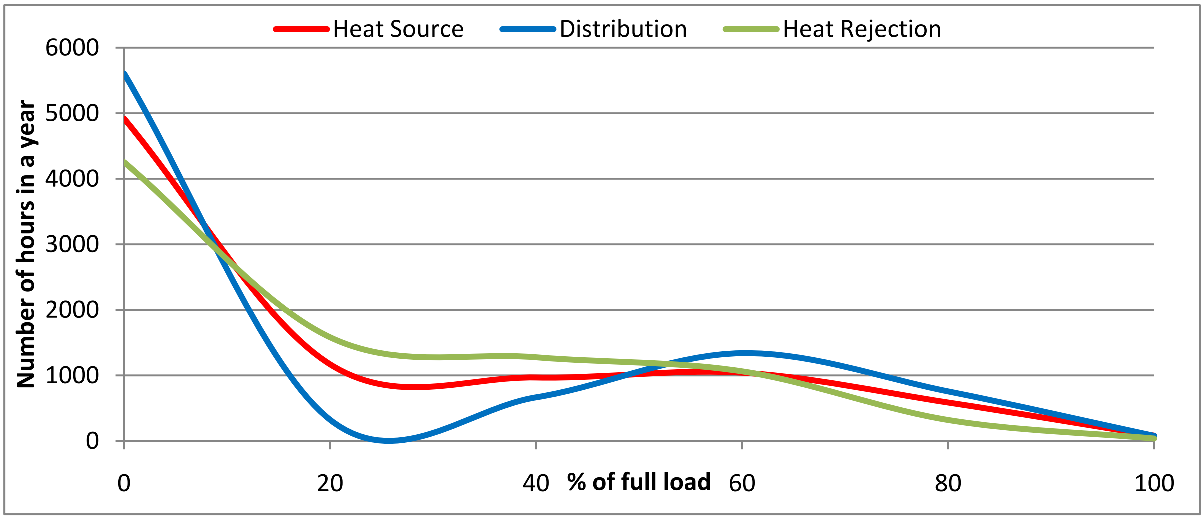


Figure 20*:* Pump duration curve for a typical Solar Cooling installation. Here it is apparent that good partial load efficiency is necessary since the system is mostly operating between 20 and 80% of full capacity.

In order to have high overall efficiency it is important to have good partial load efficiency. This can be solved by installing variable speed pumps in the collector- and heat rejection circuits. The temperature difference between the inlet and outlet in each circuit can be used to generate a signal to the frequency converter in the pump. A temperature difference of 10 to 12˚C is recommended. For small pumps simpler methods can be used for varying the speed.

Connection with ClimateWell SolarChiller

The ClimateWell units should be installed in the solar primary circuit to provide the installation with freeze protection, and so all components in the heat source circuit must be able to sustain vapour temperatures.

- Install throttle bypass valves on the heat source connections of every ClimateWell unit, see Figure 21.

These valves are necessary for the ClimateWell units to measure the available heat source temperature without opening their internal valves. Two or more ClimateWell units can share the same bypass valve if the TSP-temperature sensors are pasted in the same place. If no external signals are used to control the heat rejection and distribution pumps, bypasses for these circuits are also recommended.

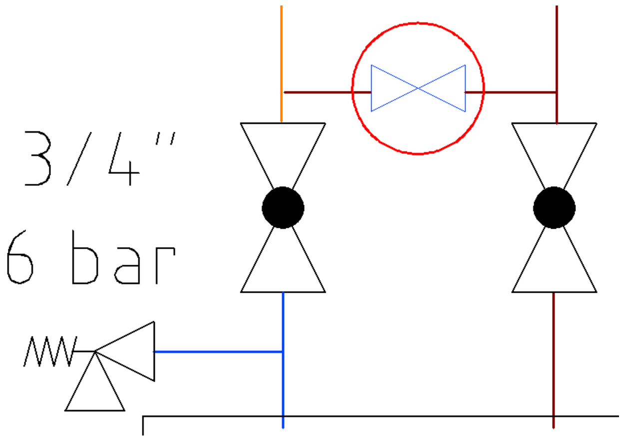


Figure 21: *Throttle bypass valve on heat source connection of the ClimateWell unit in order to measure the heat source temperature even when the internal valves in the ClimateWell unit are closed. The temperature sensor must be pasted on the flow pipe before the bypass valve.*

- Service valves and safety valves should be installed in every connecting circuit in accordance with Figure 21.

Several ClimateWell units can be installed in parallel in order to increase power output. In this case follow the procedures below.

- Install a pressure operated bypass valve before the first ClimateWell unit in order not to harm a powerful pump, see Figure 22.
- Install reversed return pipes on all three circuits in order to obtain the same flow through each unit.

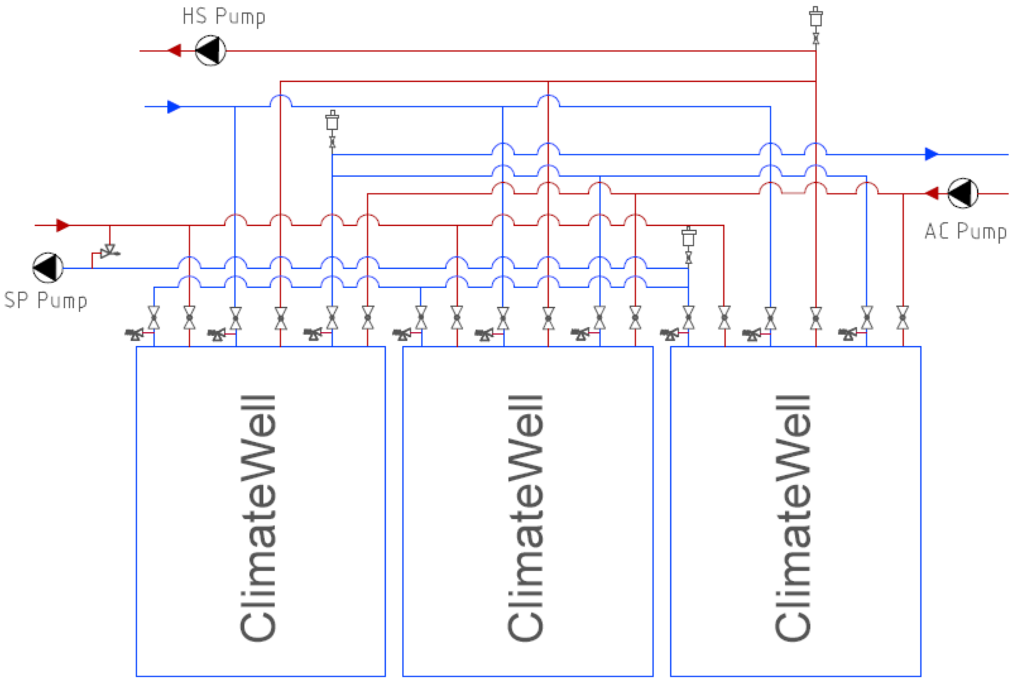


Figure 22: *Connection with several ClimateWell units in parallel. Reversed return pipes are used in order to obtain the same flow in each unit for any flow.*

The following figures are examples of how a ClimateWell unit can be connected to different external systems. They are only conceptual drawings and do not include all necessary components.

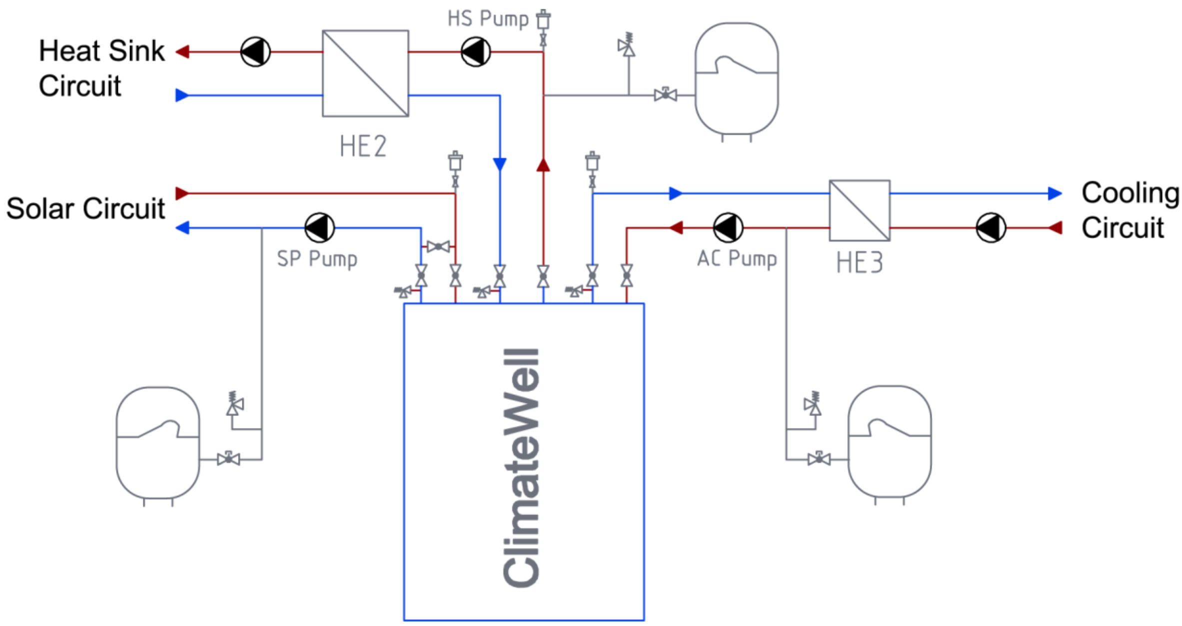


Figure 23*: A single ClimateWell unit connected to a water distribution circuit without a cooling backup system.*

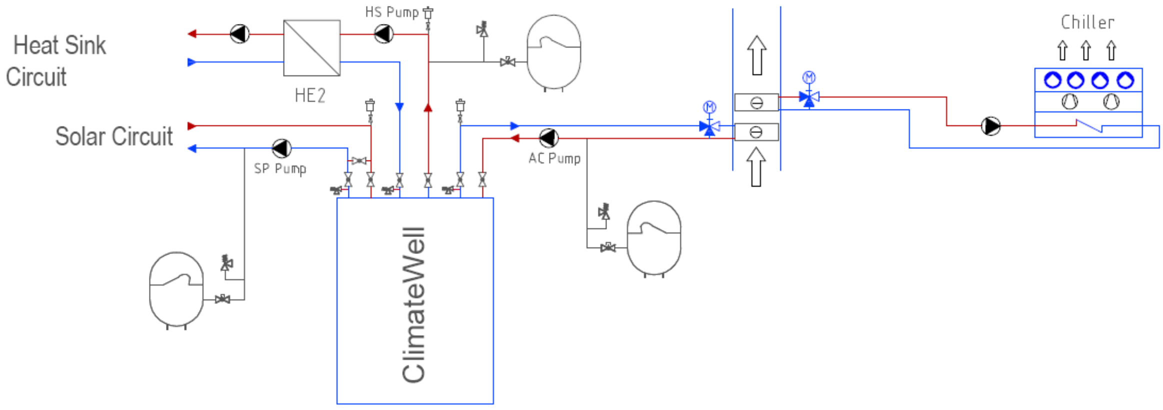


Figure 24: *A single ClimateWell unit connected to the primary coil of an air handling unit with a secondary coil connected to a backup chiller.*

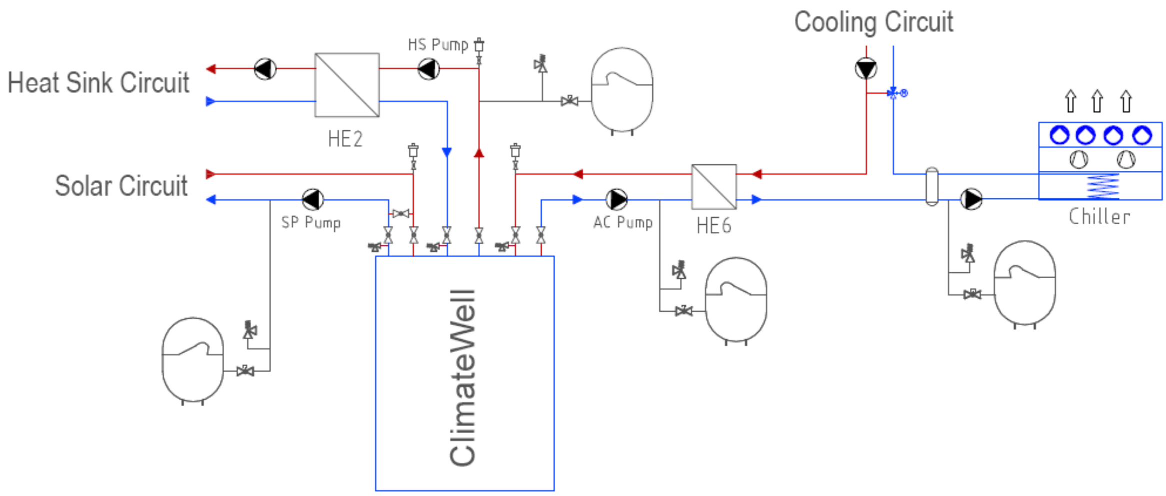


Figure 25: *A single ClimateWell unit connected to a water circuit in series with a backup chiller. The chiller flow should be close to the design flow of the ClimateWell cooling circuit.*

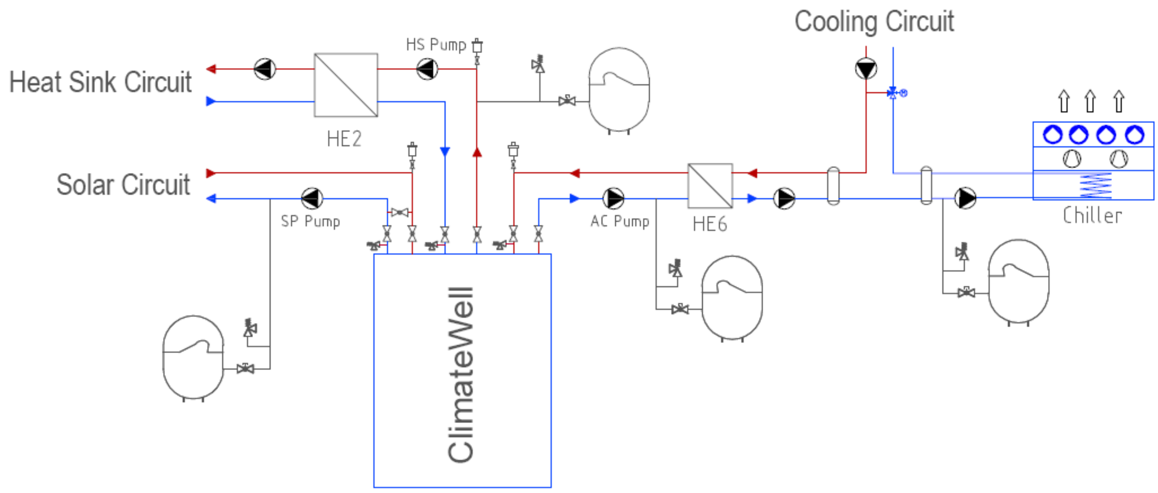


Figure 26: *A single ClimateWell unit connected to a water circuit in series with a backup chiller. The distribution flow is higher than the design flow of the ClimateWell cooling circuit.*

Control System

Control Logics

Detailed information on possible control logics suitable for the schematics in Figure 28 and Figure 29 is found in Appendix 2. The logic for the distribution system is assumed to be done by the building monitoring system and has not been contemplated in Appendix 2.

Communication with ClimateWell

The ClimateWell units can communicate with the external control system through 0-5 V signals or through RS232. More information on communication with ClimateWell can be found in ClimateWell's Control System Manual.

Solar Schematics

The recommended Solar Cooling schematics have been designed to offer robust, reliable and efficient installations using only standardized solutions readily available on the market. Always communicate any deviation from the recommended schematics to ClimateWell's project management department.

Hydraulic Drawings

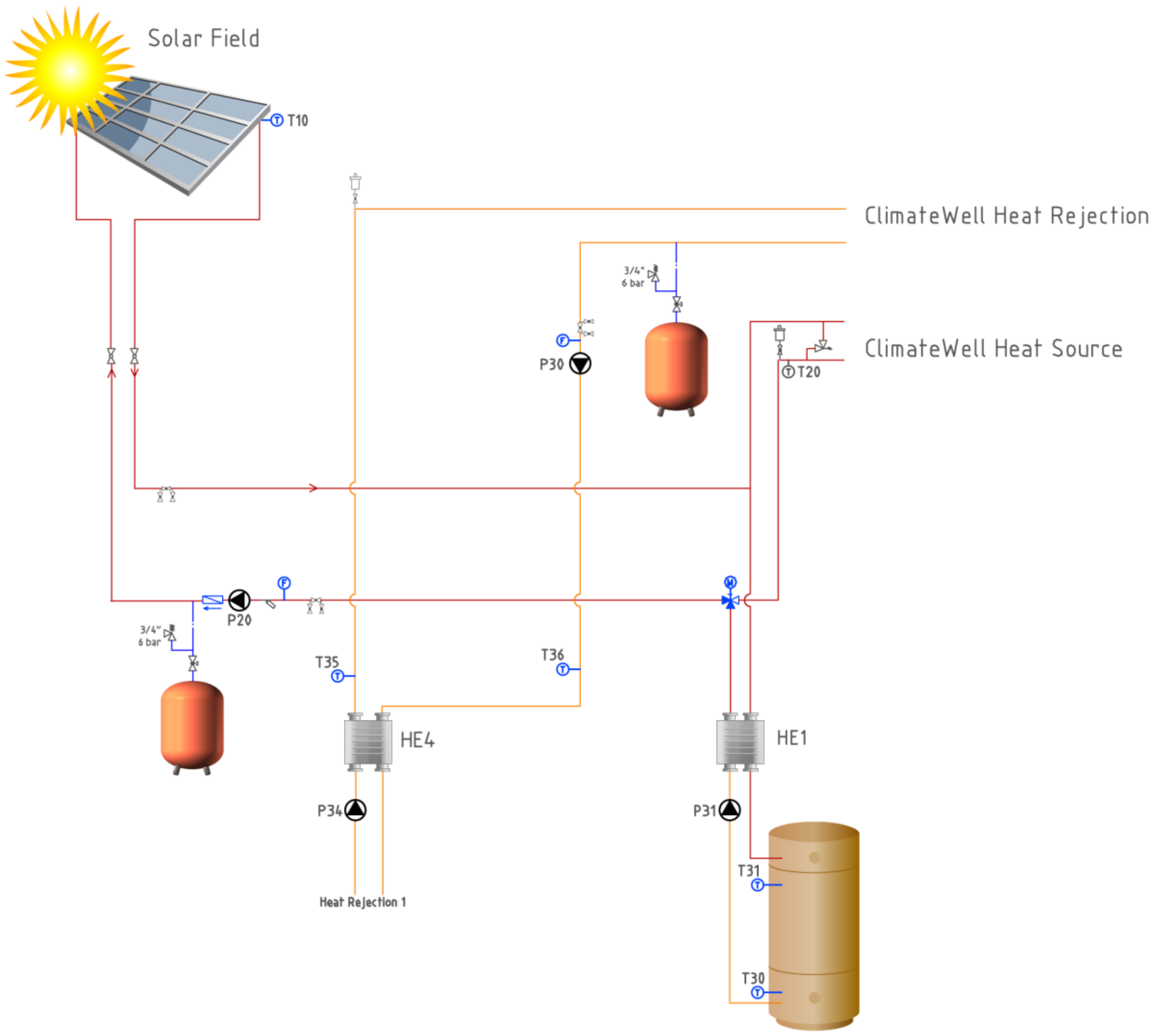


Figure 27: *Possible schematic for small installations where preheating of domestic hot water not is economically viable. The residential sector is one such example. An internal coil in the storage tank can be used instead of an external heat exchanger.*

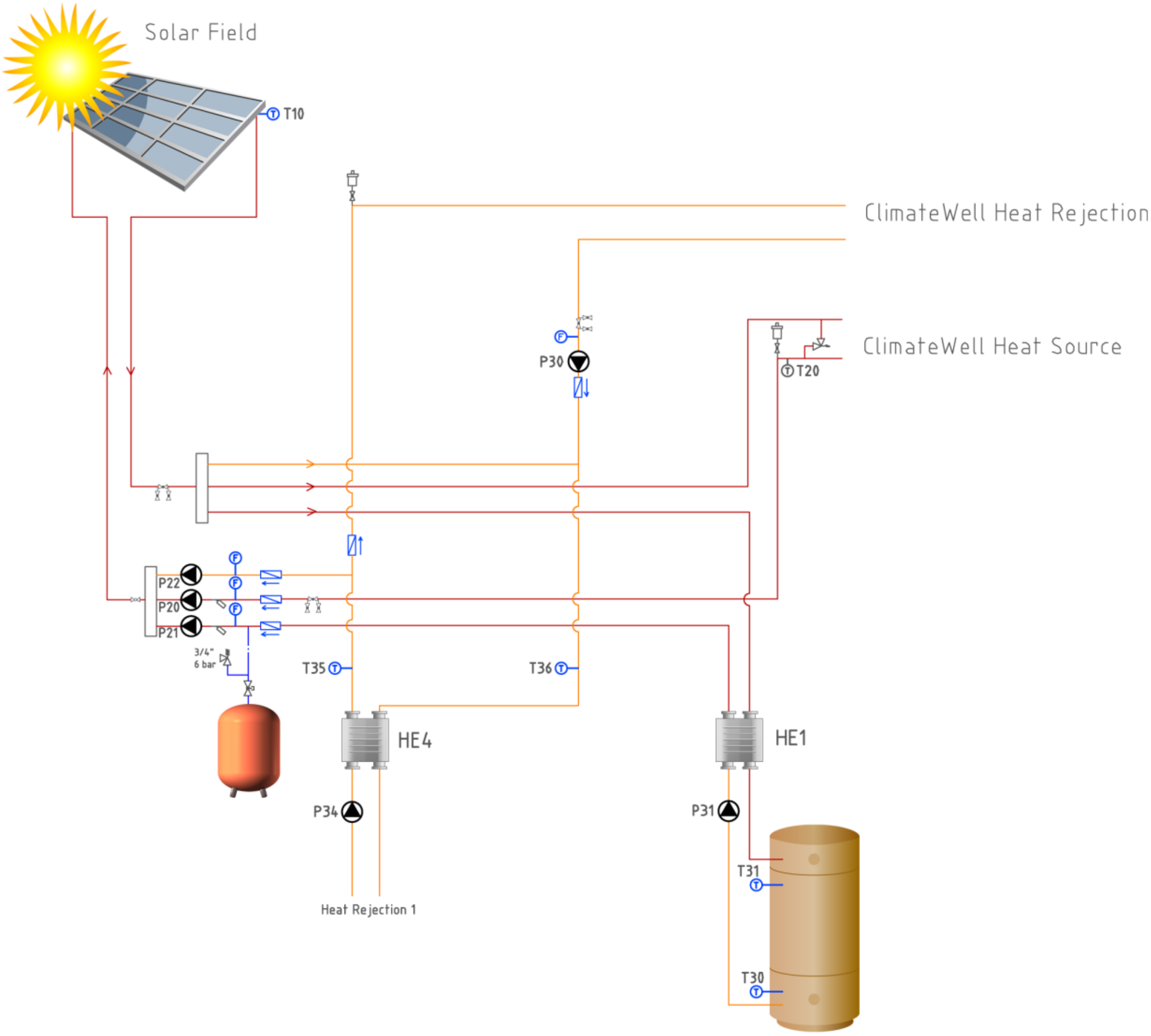


Figure 28: *Possible schematics for installations where it is desired to feed the buffer tank and the ClimateWell units simultaneously. For small installation an internal coil in the storage tank can be used instead of an external heat exchanger.*

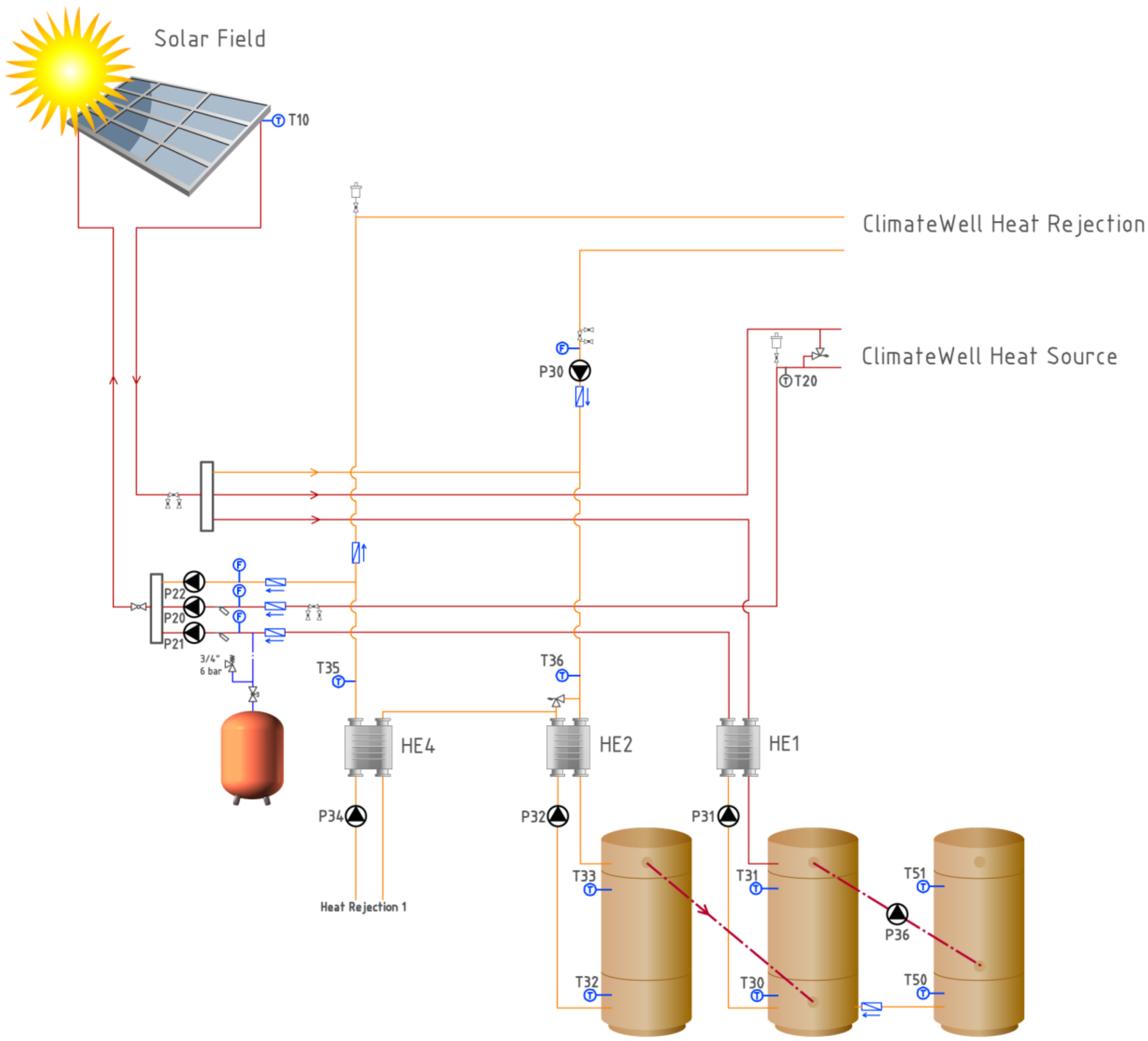


Figure 29: *Possible schematic for installations with high demand for domestic hot water. The control logics in Appendix 2 have been designed for this schematic. P21 must have variable flow in order work simultaneously with P20.*

Appendix 1

Technical Data

		ClimateWell SolarChiller
Nominal Power	Cooling	*See Power Curves*
Average Power Consumption	Electrical	18 W
COP	(Thermal)	Triple state absorption process COP 0.68. Implemented COP will depend on installation characteristics, typically 0,52-0,57.
The Maximum Temperature to ClimateWell	From Heat Source	120°C
Maximum Pressure	From Heat Source	10 bar
Pressure Drop	Heat Source Circuit	30 kPa at 25l/min
	Heat Rejection Circuit	38 kPa at 50l/min
	Distribution Circuit	45 kPa at 25l/min

Energy Storage Capacity	Cooling	56 kWh
Dimensions	H x W x D	2038 x 1211 x 807 mm
Weight		990 kg
Fluid Volume	Operational	74,5 l
Salt Solution	Lithium chloride	LiCl

Operational Data

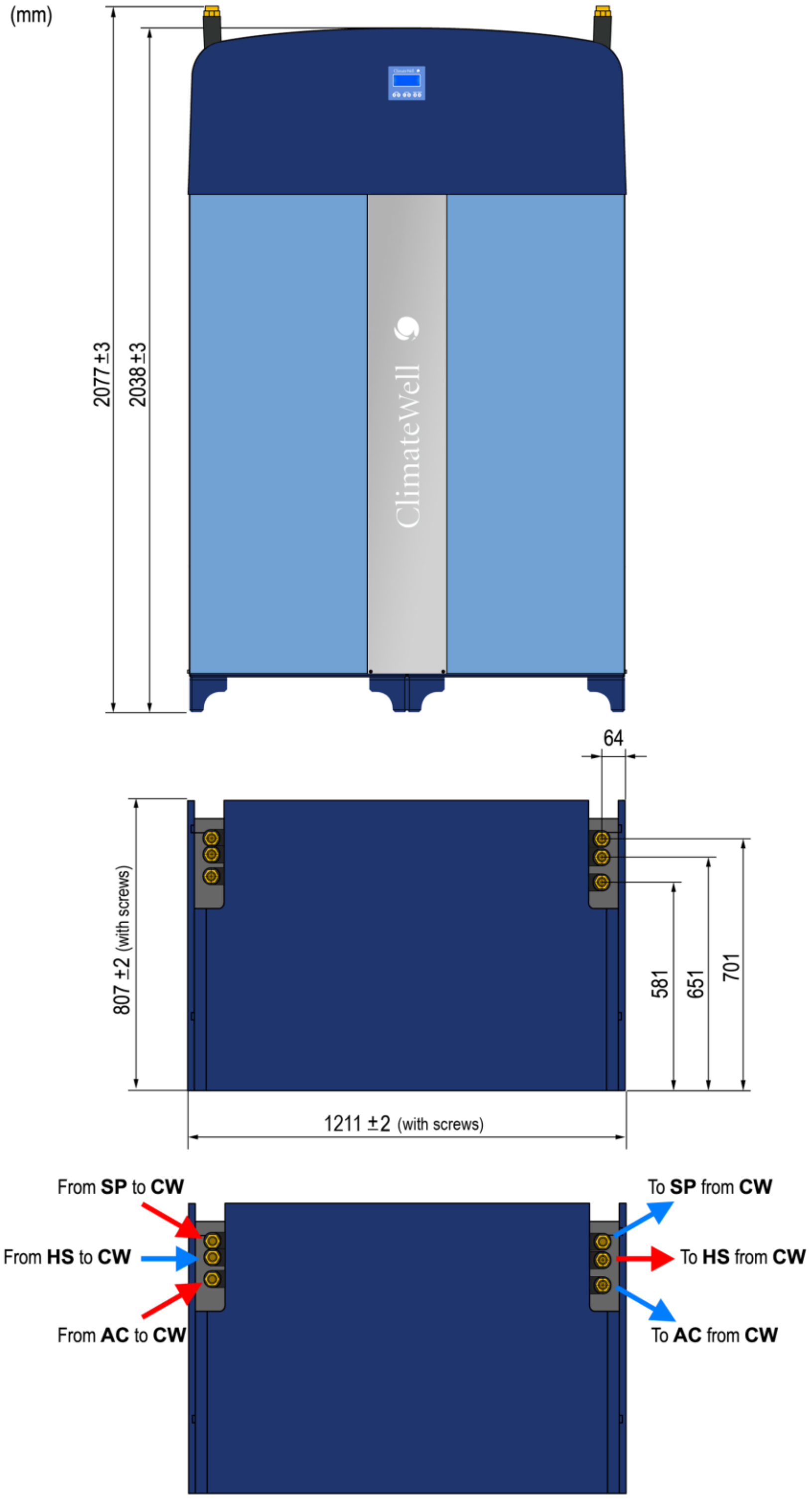
			ClimateWell SolarChiller
Heat Source Circuit	Flow		25 - 30 l/min
	Typical Power Range		15 - 20 kW
	Operational Temperature	Out	75 °C – 100 °C
		In	85 °C – 110 °C
	Maximum Pressures		6 bars
	Type of Fluid		Propylene Glycol 1,2 L ≥ 15 % concentration
Distribution Circuit	Flow		25 - 30 l/min
	Nominal Power		*See Power Curves*
	Operational Temperature	Out	10 °C – 16 °C
		In	15 °C – 21 °C
	Type of Fluid		Propylene Glycol 1,2 L ≥ 15 % concentration
Heat Rejection Circuit	Flow		50 - 60 l/min
	Typical Power Range		20-30 kW
	Operational Temperature	Out	30 °C to 45 °C
		In	< 30 °C
	Type of Fluid		Propylene Glycol 1,2 L ≥ 15 % concentration

Electrical Connections and Control

		ClimateWell SolarChiller
Electrical connections	Vac	230
Communication	Protocol	RS 232 19200, 8,None, 1
Output Signals	AC pump	On/off (5V/0V 20 mA)
	SP pump	On/off (5V/0V 20 mA)
	HS pump	On/off (5V/0V 20 mA)
	Output mode status	Cooling/Heating (5V/0V 20 mA)
Input signals	Output mode	Normally open Toggle between heating and cooling when closed
	AC pump status	On/off (5V/0V 20 mA)

Hydraulic Connections

ClimateWell SolarChiller

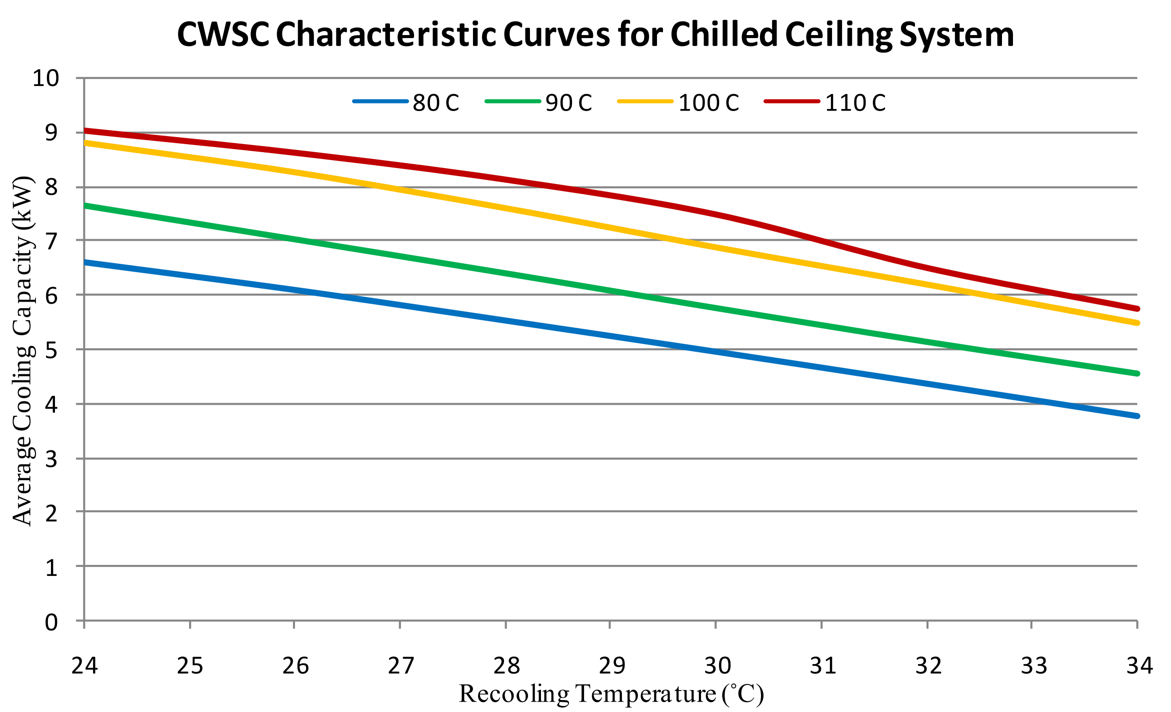


Connection diameter: 28 mm

Power Curves

Please Note! The curves below are made for 20 °C distribution return temperature.

ClimateWell SolarChiller



Appendix 2

Input and Output Signals

	Sensors	Type
T10	Collector_Out	Temperature
T20	CW Return	Temperature
T30	Tank1Lower	Temperature
T31	Tank1Upper	Temperature
T32	Tank2Lower	Temperature
T33	Tank2Upper	Temperature
T50	Tank3Lower	Temperature
T51	Tank3Upper	Temperature
T35	CWHSReturn	Temperature
T36	CWHSFlow	Temperature

	Boolean Inputs	
	Summer_Mode	

	Required Outputs	Type	Settings	Defaults
P20	CW Solar_Pump	Relay	DeltaTOn	10 °C
P21	DHW Solar_Pump	Relay	DeltaTOff	4 °C
P22	Solar_Pump3	Relay	Collector1min	60 °C
P30	CWHSPump	Relay	Collector1max	130 °C
P31	DHWSecondaryPump	Relay	Collector1minDHW	70 °C
P32	PreheatPump	Relay	Tank1Max	90 °C
P34	CoolTowerPump	Relay	DWHTimer	1 Min
P36	TransferPump2	Relay	Tank1Hysterisis	4 °C
			TTankTransferON	12 °C
	CWHSPump_Speed	0 – 10 V	TTankTransferOFF	6 °C
	CW Solar_Pump_Speed	0 – 10 V	TRecooling	28 °C
	DHW Solar_Pump_Speed	0 – 10 V	Solar_Pump_Speed_Min	10 %

Logics

```
IF Summer_Mode = TRUE THEN
        IF T10 > T20 + DeltaTOn AND T10 > Collector1Min AND T10 < Collector1Max - 20  THEN
                CW Solar_Pump = On

        IF T10 < T20 + DeltaTOff  THEN
                CW Solar_Pump = Off
        ELSE IF T10 < Collector1Min THEN
                CW Solar_Pump = Off
        ELSE IF T10 > Collector1Max THEN
                CW Solar_Pump = Off

        IF T10 > Collector1minDHW AND T31 < Tank1Max - Tank1Hysterisis AND T10 > T30 + DeltaTOn
        THEN
                DHW Solar_Pump = ON AND DHWTimer = ON
        IF DHWTimer = 0 THEN DHWSecondaryPump = ON
        IF T10 < Collector1minDHW - DeltaTOff THEN
                DHW Solar_Pump = OFF AND DHWSecondaryPump  = OFF
ELSE
        IF T31 < Tank1Max - Tank1Hysterisis AND T10 > T30 + DeltaTOn THEN
                DHW Solar_Pump = ON AND DHWTimer = ON
        IF DHWTimer = 0 THEN DHWSecondaryPump = ON
        IF T10 > T32 + DeltaTOn AND T10 < Collector1Max AND T33 < Tank1Max - Tank1Hysterisis
        AND DHW Solar_Pump = OFF THEN
                Solar_Pump3 = ON
        IF T10 < T32 - DeltaTOff THEN
```

```
                Solar_Pump3 = OFF
        ELSE IF T10 > Collector1Max
                Solar_Pump3 = OFF
        ELSE IF T33 > Tank1Max
                Solar_Pump3 = OFF
        ELSE IF DHW Solar_Pump = ON THEN
                SolarPump3 = OFF
END IF

IF T31 > Tank1Max THEN
                DHW Solar_Pump = OFF AND DHWSecondaryPump  = OFF
ELSE IF T10 < T30 + DeltaTOff THEN
                DHW Solar_Pump = OFF AND DHWSecondaryPump  = OFF

IF T31 > T50 + TTankTransferON THEN
                TransferPump2 = ON
IF T31 < T50 + TTankTransferOFF THEN
                TransferPump2 = OFF

IF T35 > TRecooling AND CWHSPump = ON THEN
                CoolTowerPump = ON
IF T35 < TRecooling - 1 THEN
                CoolTowerPump = OFF
IF CWHSPump = OFF AND Solar_Pump3 = OFF THEN
                CoolTowerPump = OFF

IF T36 > T32 + DeltaTOn AND (CWHSPump = ON OR Solar_Pump3 = ON) THEN
                PreHeatPump = ON
IF T36 < T32 + DeltaTOff THEN
                PreHeatPump = OFF
IF CWHSPump = OFF AND Solar_Pump3 = OFF THEN
                PreHeatPump = OFF

IF T10 > 120 AND T10 < Collector1Max THEN
                Solar_Pump3 = ON
                CoolTowerPump = ON
IF T10 < 110 THEN
                Solar_Pump3 = OFF
```

Index

Reference

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