

PRODUCT DESCRIPTION

ClimateWell™ 10

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Approved by PO/JL

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ClimateWell™ 10

Solar-Thermal Air Conditioning

✓ **Stores energy to use when required**
 ✗ **No refrigerants**

ClimateWell 10 is a highly efficient solar air conditioning unit with the unique ability to store energy and to deliver cooling and heating. The patented triple-state absorption technology allows ClimateWell 10 to be the first product to make efficient and integrated energy storage possible. The process cycles between three states of aggregation – solid, liquid and gas – allowing continuous cooling or heating output. ClimateWell 10 also works in conjunction with other thermal sources such as district heating or micro co-generation.

The figure below shows the contents and dimensions of ClimateWell 10, which includes two barrels and a plumbing unit (with transparent covers).

ClimateWell 10 can operate in three modes – charging, heating and cooling. Charging mode stores energy by drying a salt (Lithium Chloride - LiCl) that subsequently can be used whenever required.

It's important to note that the machine can charge and discharge simultaneously. This means that it can continuously receive thermal energy, and at the same time, deliver heating or cooling. The system can also heat domestic hot water or a swimming pool.

Mode	Storage Capacity *	Maximum Output Capacity **	Electrical COP ***	Thermal Efficiency
Cooling	60 kWh	10/20 kW	714	68%
Heating	76 kWh	25 kW	1786	160%

* Total storage capacity (i.e. including both barrels)

** Cooling capacity per barrel: 10 kW cooling is the maximum capacity. If both barrels are used in parallel (double mode) the maximum cooling output is 20 kW and the maximum heating output is 25 kW.

*** Coefficient of Performance (COP) = cooling or heating output (kW) divided by electrical input. The only electrical input is the internal controls. COP in conventional compressor-based chillers and packaged air conditioning units is usually stated as cooling capacity (kW) divided by compressor electrical input. Since the ClimateWell 10 doesn't have a refrigeration compressor, COP is stated here as cooling/heating power delivered divided by total electrical power of the internal controls.

Operation

Three external circuits are connected to the ClimateWell 10:

- Thermal heat source (e.g. solar collectors)
- Air conditioning distribution system for cooling and heating (e.g. radiant floor, fan-coil units)
- Heat sink for charging and discharging (e.g. swimming pool, cooling tower, air cooled condenser or geothermal holes)

ClimateWell 10 is a modular absorption machine that differs from the “standard” Lithium Bromide type absorption machines in three main aspects:

- It has internal storage in each of the two accumulators. This allows the machine to store chemical energy with a very high density. This energy can subsequently be used both for cooling and heating. It is important to emphasise that this is chemical energy, not thermal energy that is stored.
- It works intermittently with two parallel accumulators (Barrel A and Barrel B).
- It is designed to use relatively low temperatures and is hence optimized for usage with solar thermal collectors. It also works with a stable temperature inside the accumulators, which in turn allows for an effective use of solar thermal collectors.

ClimateWell 10 is made up of two “barrels” each consisting of a reactor and condenser/evaporator. The two barrels can operate in parallel; read more about this in the “Control Strategy” chapter on page 11.

Charging

The Process

Hot liquid from the thermal source enters ClimateWell 10 reactor heat exchanger. Normally the liquid from the thermal source needs to be at least 50°C above the heat sink temperature for charging. If the thermal source is solar collectors, then this temperature will depend on the power delivered by the solar collectors, which in turn depend on the solar radiation, flow rate and the size and efficiency of the collectors.

When the entering heat reaches the reactor heat exchanger, it causes the LiCl solution in the reactor to boil. When boiling the LiCl returns to crystalline form. At the same time the water evaporates and steam is released to the condenser/evaporator where it condenses on the heat exchanger with the relatively lower temperature.

In most cases, when running the system on solar thermal energy, it is recommended that a back-up thermal source such as a small gas-boiler or a simple electric element be installed in parallel to complement the thermal source in the event of prolonged cold/cloudy periods.

The example below shows the energy balance during charging. Some 44 kWh are required to charge one barrel, giving the heat sink 30 kWh of energy. In winter, this energy can be sent directly to the building distribution system (see more about this in the “Heating” chapter).



Dimensioning Data

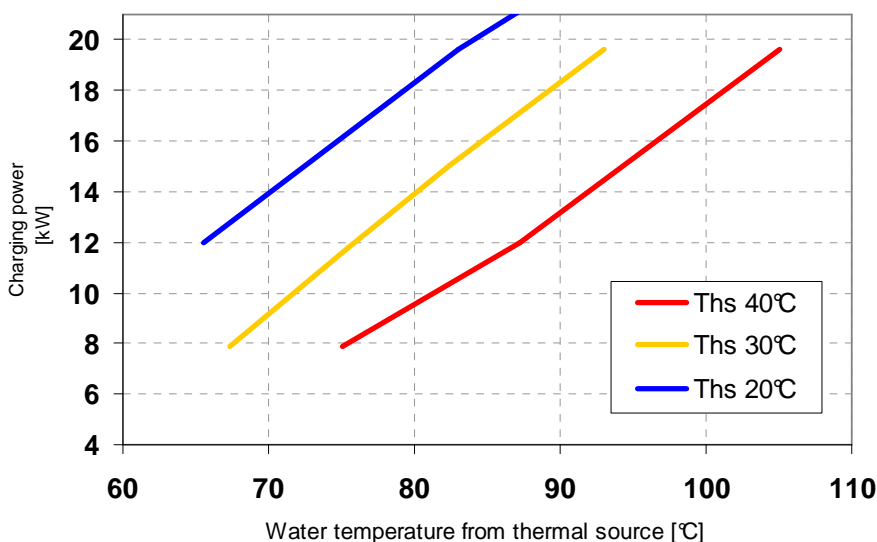
The maximum continuous charging temperature is 95°C, but 120°C is possible under shorter periods (minutes). If the solar thermal panels are well dimensioned, this should not occur. If the charging power is higher than the recommended maximum power, the return temperature to the panels will consequently increase the charging temperature. The two barrels can be charged in parallel, thus doubling the charging power (more about this in the “Control Strategy” chapter).

The typical flow rate for the solar thermal panel circuit is 15 l/min.

The following chart shows charging power (15l/min) per barrel at 30% charging level (100% meaning fully charged) as a function of:

- Hot Water Temperature from the Thermal Source and
- Liquid Temperature from the Heat Sink (Ths)

ClimateWell 10 charging performance



Notes:

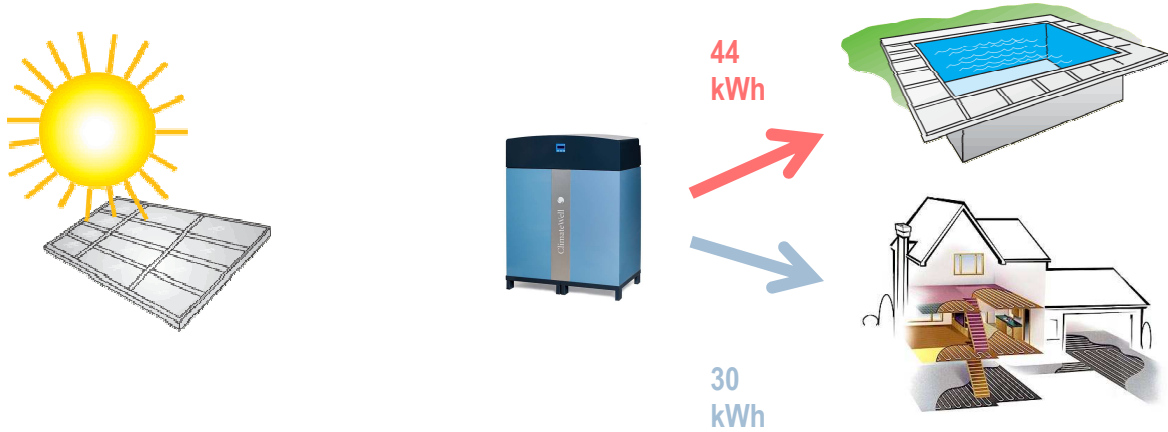
- Maximum power is 26 kW per barrel resulting in 52 kW total if charging both barrels at the same time.
- Charging example:
 - If we have 83°C from the thermal source and 30°C from the heat sink, then the charging capacity would be 15 kW per barrel.
 - In terms of energy, 88 kWh is required to fully charge both barrels, thus fully charging one empty barrel would take 44 / 15 = 2 hours and 56 min.
- When reaching a fully charged level, typically a 5°C higher temperature is required to achieve the same charging power.

Cooling

The Process

The water returns from the distribution system at a higher temperature than when it left the condenser / evaporator (we have cooled the building). This heat causes the water in the evaporator to boil and the steam passes down to the reactor, where it condenses, since the reactor is relatively cooler. Steam that condenses into water in the reactor will dilute the LiCl solution.

The example below shows one of the two barrels discharging cooling.



Dimensioning Data

It is important to note that low temperatures from the heat sink improve

ClimateWell 10's cooling capacity, so selection of the type and size of heat sink is important to optimise performance and minimise cost. Temperature from the heat sink will depend on the ambient conditions, the size and efficiency of the heat sink. (See also the "Heat sink" section).

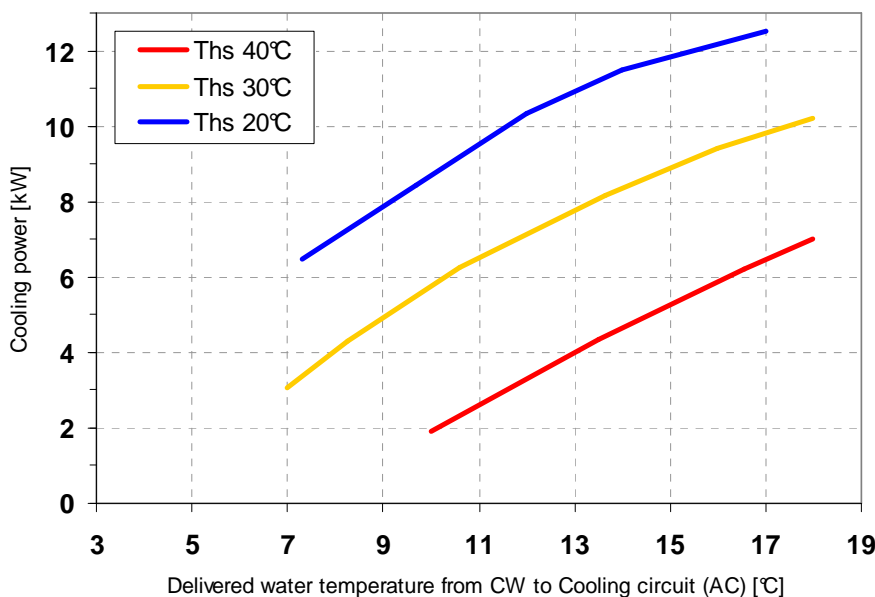
If the cooling load increases in the building to a point where the maximum power of the machine is reached, the distribution circuit temperature will start to increase slowly, but will still cool the building. The indoor temperature will increase, but still be lower than the outdoors. Usually, it is not recommended to have a great difference between indoor and outdoor temperature when it is very hot outside.

The typical flow rate for the building distribution circuit is 15 l/min.

The following chart shows the cooling capacity (15l/min) per barrel when fully charged as a function of:

- Chilled Water Temperature from ClimateWell 10
- Liquid Temperature from the Heat Sink (Ths)

ClimateWell 10 Cooling performance



Notes:

- The higher the temperature to the distribution system, the more effectively ClimateWell 10 works in cooling mode. It is thus ideal for radiant floor/wall/ceiling applications, where flow temperatures up to 17°C are used.
- Thermal COP = 0,68 (stable)
- Where lower chilled water temperatures are required, such as for a classic 7°C fan coil system, an effective heat sink (e.g. cooling tower) should be considered.
- Cooling example:
If we have 30°C from the heat sink and deliver 15°C to the (radiant floor) cooling circuit, then the cooling power per barrel would be 9 kW. If both barrels are discharged at the same time, the cooling power would be 18 kW.
- When 70% of the energy is discharged the delivered power is typically 2 kW lower, giving the example above 7 kW of power.

Heating

The Process

Heating is just cooling in reverse, meaning that the charged energy is extracted as heat by connecting the condenser/evaporator to the heat sink and the reactor to the distribution system.

Water returns from the distribution system at a lower temperature than when it left the reactor (we have heated the building). This water boils the water in the condenser/evaporator and steam passes down to the reactor. Steam condenses into water which dilutes the LiCl solution in the reactor.

During discharging, the heating energy is extracted by connecting the evaporator to the heat sink and the reactor to the distribution system. Under charging, heat can also be extracted by connecting the condenser to the distribution system under charging mode.

The example below shows one of the two barrels discharging heating.



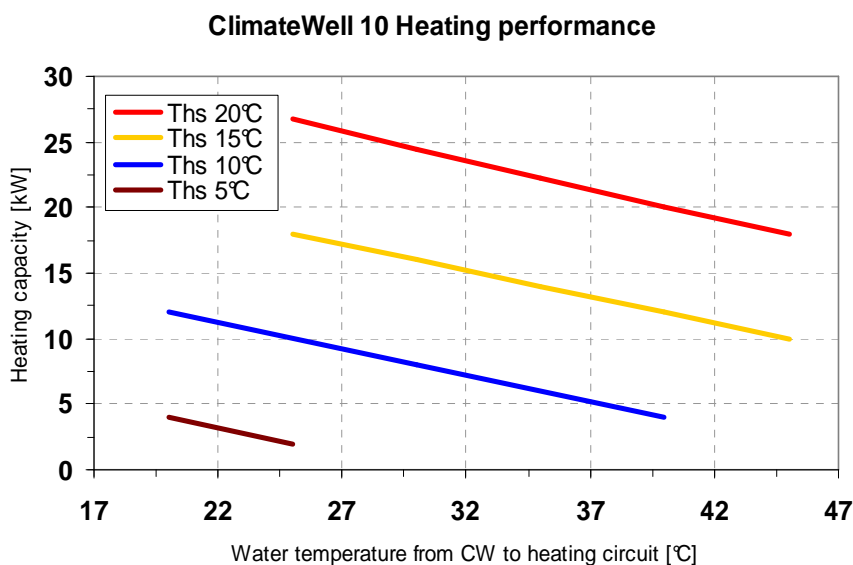
Dimensioning Data

It is important to note that when using ClimateWell 10 as a heat pump in winter there must be a source from where energy can be extracted during discharging. In other words, the heat sink needs to be for example a swimming pool, geothermal loops or an air cooled condenser used in daytime. Use the graph below to find the heating power depending on different heat sink temperatures. The temperature from the heat sink must never drop below 0°C as this may cause the water in the evaporator to freeze. With a well dimensioned heat sink it is possible to increase the burner efficiency of up to 40% in winter and still use the solar collectors for domestic hot water.

The thermal source can of course be connected directly to the distribution system and hence provide heating without passing through ClimateWell 10. Any excess heat can then charge ClimateWell 10 and be used later for heating or cooling as described above. The typical flow rate for the building distribution circuit is 15 l/min.

The following chart shows the discharging heating capacity (15l/min) for both barrels when fully charged as a function of:

- Hot water temperature from ClimateWell 10
- Liquid temperature from the heat sink (Ths)



Notes:

- The lower the temperature to the distribution system, the more effectively ClimateWell 10 works in heating mode. It is thus ideal for radiant floor/wall/ceiling applications, where flow temperatures as low as 27°C are used.
- Thermal COP = 0,85 (stable)
- The back-up thermal heat source (such as a boiler, burner or electric element) can be used to add heating capacity on extremely cold days or if the solar collector power is insufficient.
- Heating example:
 - If we have 10°C from the heat sink and deliver 30°C to the (radiant floor) heating circuit, then the heating power would be 7,5 kW.

Thermal Heat Source

ClimateWell 10 receives its energy from the thermal heat source hot water. The thermal energy source could be solar thermal panels, district heating or waste heat from a cogeneration (CHP) plant.

During charging, water from the thermal source should be at least 50°C above the heat sink temperature. If the thermal source is solar collectors, then this temperature will depend on the power delivered by the solar collectors. This in turn depends on the solar radiation, the size and efficiency of the collectors and the circuit flow rate. It is important to note that ClimateWell 10 does not need the temperature or flow rate controlled, but will only charge with different power depending on the temperature and flow.

In most cases, when running the system on solar thermal energy, a back-up thermal source is recommended such as a small gas-fired boiler or a simple electric element. Running this system in parallel boosts the thermal source temperature in the event of prolonged cold/cloudy periods.

Distribution System

The Building Distribution System can be a radiant floor, fan coil units, chilled beam/ceiling systems or central ducted heating/cooling. In cooling mode, ClimateWell 10 works more effectively the higher the temperature to the distribution system. It is thus ideal for radiant floor/ wall/ceiling applications, where temperatures of up to 18°C are used. In heating mode, ClimateWell 10 works more effectively the lower the temperature to the distribution system. It is thus ideal for radiant floor/wall/ceiling applications, where temperatures used are down to 27°C.

It is highly recommended to use ClimateWell 10 in combination with radiant floor/wall/ceiling systems when running on solar thermal energy. We also recommend using a control system that regulates the distributed temperature depending on the indoor temperature and humidity.

The thermal source can of course be connected directly to the distribution system and hence provide heating without passing through ClimateWell 10. Any excess heat energy can then be charged in ClimateWell 10 and used later for heating or cooling.

Heat Sink

In theory there are two heat sink circuits connected to ClimateWell 10:

- Heat sink for charging
- Heat sink for discharging (cooling or heating)

The two heat sink circuits could, however, be connected to the same external heat sink, thus reducing the number of external circuits to three (thermal source, distribution system and heat sink). Use of only one heat sink is normally best and the most cost-effective configuration.

Possible heat sinks for ClimateWell 10:

- 1) Outdoor swimming pool. Heating pool water, thus using the energy twice (this is called “exergy”).
- 2) Pre-heating system for domestic hot water, if there is a large requirement of hot water for showers, kitchen, laundry, etc. Hotels and hospitals are recommended to use this.
- 3) Evaporative cooling tower is most effective for large installations. Note that closed-loop evaporatively-cooled heat exchangers are now available with performance equal to a cooling tower, but without the risk of Legionnaires’ disease and hence no need for chemical water treatment.
- 4) Air cooled condenser. Most common for single family home installations. If the building has forced ventilation, this can be used to increase the performance by passing the air from the ventilation system through the air-cooled condenser.
- 5) Geothermal circuits, such as bore holes or earth loops. A very good year round solution for ClimateWell 10.

Lower temperatures from the heat sink improve ClimateWell 10’s cooling capacity, so selection of the type and size of heat sink is important to optimise performance and minimise cost. Temperature from the heat sink will depend on the ambient conditions and the size and efficiency of the heat sink.

The heat sink receives 76% of the energy from the thermal source, and the dimensioning power of the heat sink for one charging barrel is 10 kW. At the same time ClimateWell 10 discharges power to the heat sink from the other barrel with a dimensioning power of 10 kW. Therefore the dimensioning power of the heat sink at the flow rate of 30 l/min is 20 kW.

Electrical Properties

- ClimateWell 10 draws 230 V single phase AC.
- 30 W is needed for the internal control system of the machine.
- Full load amps are 0,5 A.

Environmental Properties

ClimateWell 10 can produce up to 10 kW of cooling power with just 10 W of electrical power input. A great deal of electrical energy can be saved if ClimateWell 10 is replacing a compressor type chiller. Take into consideration that most electrical power is produced by burning fossil fuels resulting in CO₂ emissions. A typical single family home in Spain could save around 15 tons of CO₂ per year.

ClimateWell 10 contains no refrigerants and all materials can be recycled. The LiCl solution can also be recycled.

Physical dimensions and installation site requirements

Transport measurements of ClimateWell 10 are:

- 1 200 mm wide
- 800 mm deep
- 1 600 mm high

The total weight of ClimateWell 10 including the connection unit is 875 kg.

The connection unit itself weighs 64 kg. The connection unit (the plumbing module placed on top of the machine) includes all the necessary valves.

The inclination of the floor where ClimateWell 10 is installed, should be less than 0,5%.

ClimateWell 10 shall not be subjected to temperatures below 0 °C. To avoid temperatures below 0 °C and any possible corrosion, an indoor location is recommended.

Material Specification

Insulation	:	Foamed nitrile rubber
Chemicals	:	LiCl solution
Control Unit	:	Halogen free

Specification of the Control Unit

ClimateWell 10 control system is fully integrated with a LCD display situated on the front left barrel. The control system is based on three 8-bit microcontrollers. The 24-volt control system can be used to monitor the performance and change set values such as cooling and heating temperatures.

The controls are based on 8 internal temperatures including the incoming and outgoing temperatures of the 4 heat exchangers, the temperature of the charging circuit, heat sink circuit and delivered cooling/heating making a total of 12.

The ClimateWell 10 is an automated climate control which delivers a desired set indoor temperature. In normal mode, ClimateWell 10 automatically alternates between charging and discharging of its barrels. It also automatically controls the internal salt crystallisation.

To change between heating and cooling, simply enter in the menu and change this value. This procedure is not controlled by ClimateWell 10 itself, but by the user when appropriate.

ClimateWell 10 control system does not save any data; in order to log the data, it is necessary to install a personal computer or another type of control system. With this setup, it is also possible to access other additional signals from ClimateWell 10. These additional signals can be used for an overall control system influencing auxiliary units such as a back up heater, external pumps and valves. These signals are sent through the RS-232 protocol, and can be retrieved with a serial cable.

It is important to note that the ClimateWell 10 does NOT control auxiliary units such as solar panels, water heaters or fan coils. A signal to know if the heat sink pump is needed as well as if the machine is able to charge can be acquired from the ClimateWell 10. **It is very important that this signal is used for the heat sink pump.** If not used the machine could be irreparably damaged. Later in this document, there is an example of a control system configuration for a building.

The picture below shows the ClimateWell 10 control box.



Control Strategy

ClimateWell 10 control system can be set according to the specific installation requirements. The operation strategy of ClimateWell 10 should be set during the installation dimensioning and planning with the assistance of ClimateWell engineers.

This is the setting for the general operation mode. The default setting is “Normal” which is the fully automatic mode. Always keep ClimateWell 10 in this mode during normal usage.

Manual	Fully manual mode used only for performing system tests.
Normal	<p>This is the default mode and should always be used for normal operations in a standard installation. In this mode there is an automatic solar panel overheating protection and. The ClimateWell 10 automatically controls itself to deliver the set temperature to the indoor climate (e.g. air conditioning) circuit.</p> <p>ClimateWell 10 will swap barrels either when the discharging barrel is fully discharged of energy (LevelEmpty=3% for 15 min) and the charging barrel is charged to at least 80% (LevelLoaded) OR when the charging barrel is fully charged (LevelFull=100%).</p> <p>When using a Burner as primary heat source, it is recommended to consider using the Full cycles, Double or Timer mode, since the Normal mode might spill excess energy by swapping often when having no cooling load.</p>
Full Cycles	This is a special mode to use when not charging directly with solar panels, since there is no overheating protection in this mode. ClimateWell 10 will swap only when both the discharging and the charging cycles are completed. When using a burner for charging, the charged barrel will wait, while sending a signal to the burner to shut off, until the discharging barrel is empty.
Double	In double mode, both barrels are charged at the same time and both barrels are discharged at the same time. This results in a higher cooling/heating power when in discharging and a higher charging power when in charging. However, running in this mode the discharging delivery and the charging power is not continuous and there is no solar panel overheating protection.
Timer	<p>In this mode, it is possible to set the period for charging and for discharging. For example, when there is a need to charge in night time and discharge in day time.</p> <p>To set the parameter TimerStartCharging in the settings menu or in the display to the hour when you want the CW10 to start charging. Then set the parameter TimerStopCharging to the hour when you want to start discharging. It is only possible to set one cycle per day.</p> <p>In the charging time period, both barrels will charge simultaneously and then wait until the set time for discharging. In discharging it is possible to discharge one barrel at a time, or both simultaneously by setting the TimerDischargeMode to “double” or “single”.</p> <p>When setting values above 24, they will be interpreted as 24. When setting the same values for both TimerStartCharging and TimerStopCharging CW10 will stay in charging until the timers are reset or the mode is changed.</p>

Important conclusions regarding the control strategy:

- Stored energy can be charged and discharged completely several times a day. The daily energy delivery is hence not restricted to the storage capacity.
- If energy is provided to a full barrel it will be received, processed internally in the full barrel and released through the heat sink. The energy is not used but is received, thus avoiding problems with excess thermal energy (e.g. in the solar collectors).

Connections

The pressure drop in the heat exchangers is approximately 28 kPa each at 15l/min and 28 kPa at 30 l/min.

Since three-way valves are used in all circuits liquids will eventually mix and the liquid pressure will equalize. This has to be considered if not all circuits use the same type of heat transfer liquid. If only one of the circuits uses an anti freeze heat transfer fluid for example, a heat exchanger must be installed. This also applies if using a cooling tower or a swimming pool as heat sink, since the heat transfer liquid resides in a closed system (with no contact to external oxygen).

Bypasses are installed in all three circuits, guaranteeing non-stop flow at all times. When using ClimateWell 10 in double mode, extra bypasses are needed for the solar panel (SP) circuit and the distribution system (AC) circuit to guarantee a continuous flow through all circuits.

All six (6) connections to the external circuits are 28 mm copper.

Frequently Asked Questions

Q1. *How many solar collectors do I need?*

A. As a rule of thumb, you need 30 square meters of solar collectors to charge the system quickly and to obtain enough energy. However, the area needed depends on the efficiency of the solar collector, the solar radiation of your geographic region and of course the cooling and heating needs of the building. For a hotel, with large loads of cooling and heating, a larger area may be the most cost effective. The solar collector area can thus vary between 20 and 50 square meters per ClimateWell 10 unit.

Q2. *What minimum temperature do we need from the solar collectors (thermal input/source)?*

A. As a rule of thumb, the solar collectors need to be 50°C warmer than the reference temperature (at the heat sink). If you use a swimming pool, then 25°C in the pool means minimum 75°C from the collectors. A temperature difference over 50°C translates into faster charging.

The temperatures in the distribution system (the air conditioning circuit) can be set in the ClimateWell 10 control system. The machine will hence always (when possible) keep the same output temperature. That could be 7°C for a classic fan coil system or 15°C for a more modern system such as radiant floor/wall/ceiling. The restrictions on the machine depend on the heat sink power as well as the cooling load.

Q3. *What happens when the machine is fully charged and there is still solar energy?*

A. The machine deliberately spills some of the energy but remains fully charged. The energy from the solar collectors is always received and hence there are no problems with excess heat from the solar collectors.

Q4. *Where should I put the machine?*

A. Preferable inside since ClimateWell 10 should not be submitted to temperatures below 0 °C. In order to avoid any possible corrosion and negative temperatures, a location inside is the recommended solution.

Q5. *Does ClimateWell 10 need ventilation?*

A. No.

Q6. *What maintenance is required?*

A. ClimateWell 10 requires no maintenance other than that of a conventional compressor-based air conditioning unit. We recommend checking the vacuum once a year and, at the same time, vacuum pumping it. ClimateWell 10 has two valves for vacuum pumping. ClimateWell 10 does not include a vacuum pump. This service will be provided by ClimateWell associates.

Q7. *Do we need to exchange the salt/liquid?*

A. No. The LiCl does not have to be replaced.

Q8. *What is the major difference between ClimateWell 10 and a conventional absorption chiller?*

A. ClimateWell 10 uses all three states of aggregation (solid, liquid and gas) and delivers unique characteristics in terms of an integrated, dense energy storage and a high stable COP (Coefficient of Performance). It utilizes LiCl instead of LiBr which allows it to work better with solar thermal collectors. It uses a batch process with the energy storage as a highly efficient energy buffer separating the volatile solar radiation from the delivery of cooling. ClimateWell 10 provides a stable supply of cooling and heating even when the sun "disappears" behind a cloud or during the night. This can be obtained since ClimateWell 10 includes two parallel barrels, one charging and one delivering. As soon as a charging barrel is full, the machine automatically switches and starts charging the other barrel.

Q9. *What flow rates does ClimateWell 10 work with?*

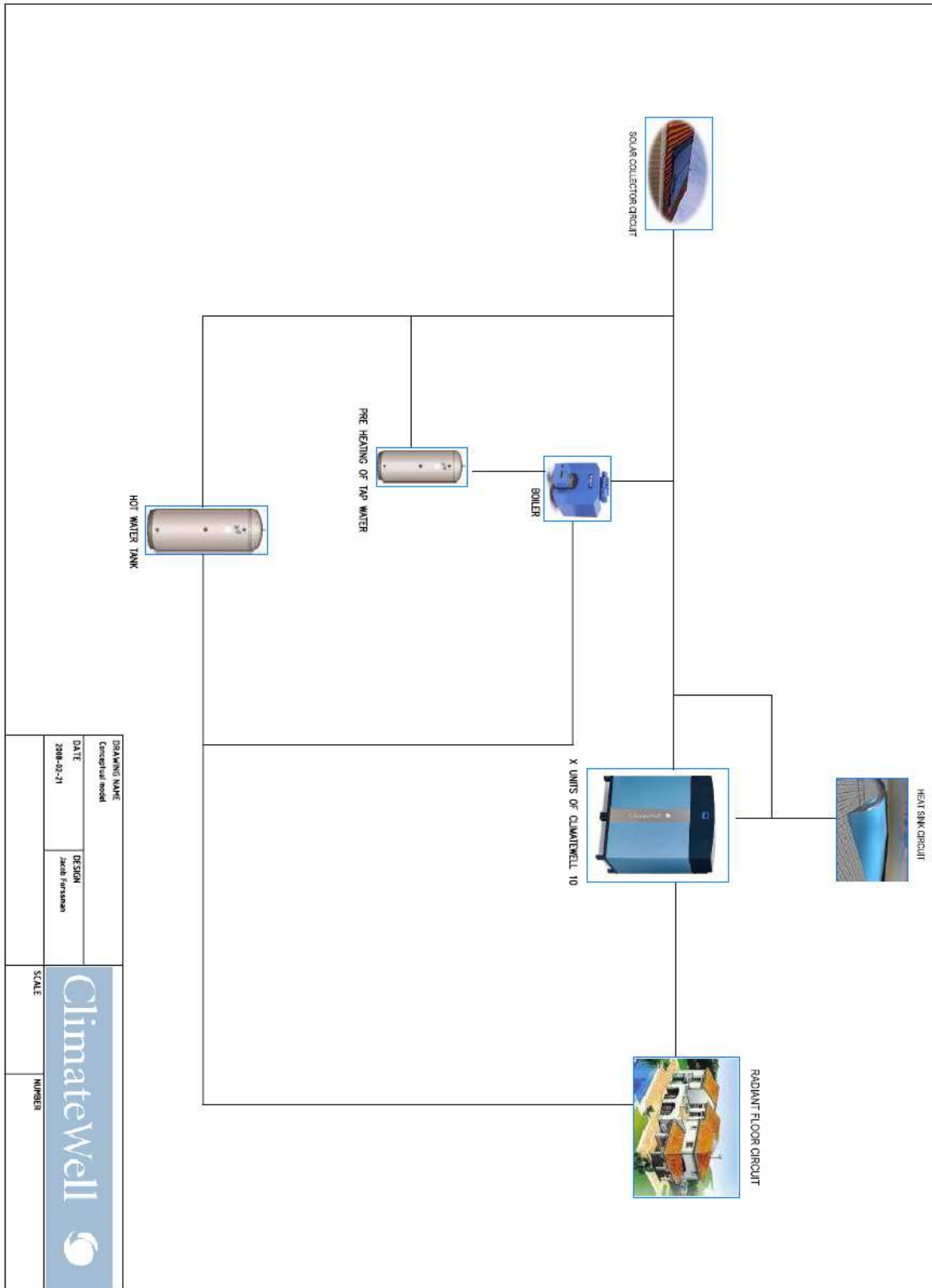
A. The recommended flow rate in the solar panel and cooling/heating circuits connected to ClimateWell 10 is 15 l/min (min 15 l/min) and in the heat sink 30 l/min. The pressure loss in each circuit is around 28 kPa at a flow rate of 15 l/min and 28 kPa at 30 l/min.

- Q10.** *How long does it take to charge the machine?*
- A.** It takes about 4 hours. Maximum input power from the solar collectors is 26 kW. Since the ClimateWell 10 has a chemical energy storage equivalent of 66 kWh and the thermal COP is 0,68 ClimateWell 10 can fully charge both barrels (if we start from zero) in 4 hours and 30 min when charging at 20 kW.
- Q11.** *Is it noisy?*
- A.** No. Since the ClimateWell 10 has no moving parts the noise produced by the machine is very low.
- Q12.** *Can ClimateWell 10 work in parallel with a conventional air conditioning system and boiler?*
- A.** Yes. In some cases a good solution is to let the ClimateWell 10 cover a base cooling load and use a conventional air conditioning system to cover the peaks. This is often the case for buildings with a large cooling need, such as hotels.
- Q13.** *Are the chemicals toxic?*
- A.** No, they are non-lethal and non-toxic in any normal dose.
- Q14.** *Is the LiCl corrosive?*
- A.** Yes, LiCl is corrosive when combined with oxygen. However, since the ClimateWell 10 is completely sealed in a vacuum, there is no oxygen inside the barrels. Therefore there is no ongoing corrosion of any importance.
- Q15.** *What is the lifetime of this product?*
- A.** Based on experience from similar salt based, non-compressor products we estimate a life time of at least 15 years.
- Q16.** *What happens when the machine reaches the end of its useful life?*
- A.** The LiCl-salt and sheet metal parts shall be recycled.
- Q17.** *How does the COP vary with temperature?*
- A.** Since we have a batch process, we have a very stable COP.
- Q18.** *If the sun hasn't been shining for 5 days, will I be without energy?*
- A.** It is best to have a backup boiler or electric element in parallel with the solar collectors to supplement if such a situation arises.
- Q19.** *What is the vacuum pressure inside the barrel?*
- A.** The vacuum pressure varies between 6 - 60 mbar depending on the steam pressure caused by the water.
- Q20.** *Is there a need for any specific certificates due to the vacuum?*
- A.** No, there is no need for pressure vessel certificates.
- Q21.** *Is it possible to install multiple ClimateWell 10 machines in parallel?*
- A.** Yes, several ClimateWell 10 machines can be installed in parallel to increase the power and capacity of energy storage. The main consideration in this case is to increase the flow rate for each extra ClimateWell 10. For example, with 3 ClimateWell 10, the flow rates should be: SP -45l/min; AC-45l/min; HS-90l/min.

Due to our policy of ongoing development and improvement ClimateWell AB reserves the right to vary configurations, dimensions, availability, etc without prior notice.

06 March 2008

ClimateWell 10 Configuration example



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