NEW CONCEPTS FOR SOLAR / THERMALLY DRIVEN COOLING

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Abstract

In the field of solar / thermally driven cooling systems recently a number of chillers have been invented and turnkey-projects have been realised. The experience of the last years shows that in addition to optimized single components the system design is the key to the successful realization of thermally driven cooling systems. Especially in view of the economic and ecological efficiency of the plants this is a significant factor. For this reason, the company Pink has developed new core components and system solutions for optimized solar / thermally driven cooling plants.

Two issues were specifically addressed:

1. Optimization of the heat rejection in terms of water sanitation and maintenance

2. New system concepts for solar cooling systems with a focus on the reduction of driving-temperature and the cooling-capacity of the chiller

1. Heat rejection

The heat rejection of thermally driven chillers is a critical subsystem because:

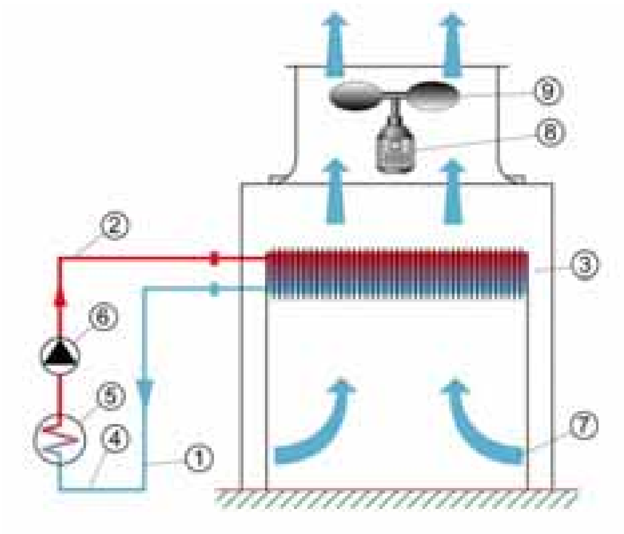
- The necessary temperature level of the driving heat and the efficiency of the system depends on the temperature level of the heat rejection system significantly
- The amount of heat to be rejected is about twice to triple bigger than the cooling load
- The electrical energy consumption as well as the initial and operating costs of the heat rejection system are significantly high

There are different heat sinks possible to reject the heat; f. ex. water, ground or air. Because air is available for almost all applications, cooling towers are often used for heat rejection. Two general systems are considered, open cooling towers (or wet cooling towers) and closed cooling towers or (dry coolers). As a combination of these adiabatic pre-cooling of the air in a dry cooler and hybrid cooling towers should be mentioned.

The main difference between these technologies is that in the dry cooler the cooling water rejects the heat to the air via a heat exchanger und in wet cooling towers the cooling water is sprayed into the air and a direct heat and mass transfer takes place. Thus in dry coolers only sensible heat and in wet cooling towers mainly latent heat is exchanged.

1.1 Dry cooler

Dry coolers are generally air-to-water heat exchangers. The cooling water circulates in a closed circuit between the chiller and the dry cooler and rejects the heat over the finned surfaces to the ambient air (Fig.1).



1. cooling circuit
2. inlet flow
3. cooling element (heat exchanger)
4. return flow
5. heat source
6. circulating pump
7. cooling air
8. fan drive
9. fan

Fig. 1: Sketch of a dry cooler [2]

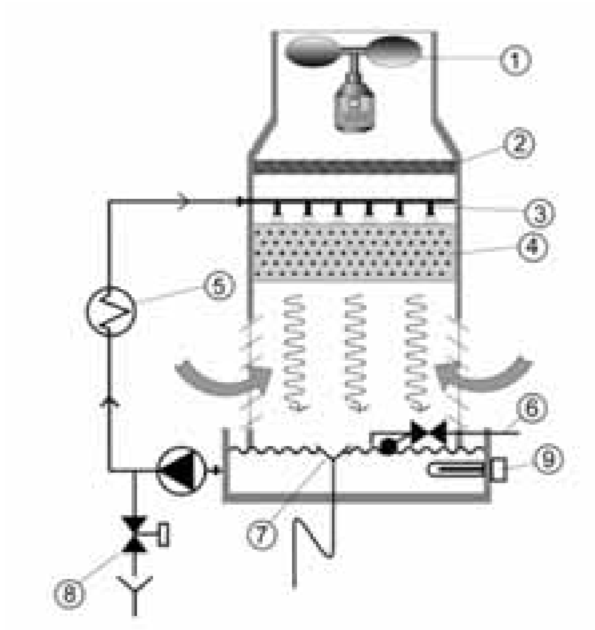
It is not possible to cool down the cooling water below the ambient dry bulb temperature. Depending on the sizing of the dry cooler the typical cooling water outlet temperatures are 5 to 9K higher than the air inlet temperature.

Because of no direct contact between the cooling water and the air dry coolers have lower maintenance costs. A further advantage is the possibility of using water/glycol mixtures which allows a full year operation.

The main disadvantages compared to wet cooling towers are higher re-cooling temperatures, much higher investment costs, energy consumption and space requirement.

1.2 Wet cooling tower

Wet cooling towers (open loop evaporative cooling towers) consist of a shell containing a packing with a large surface area. Nozzles located above the packing spray and distribute the cooling water onto the packing. The water trickles through the packing into a basin from which it is pumped back to the chiller. The water is cooled by air, drawn or blown through the packing by means of a fan. The air flow, which is either in counter flow or cross flow to the water flow, causes some of the water to evaporate, thus latent heat, is exchanged from the water to the air (Fig.2).



1. fan with drive
2. drift eliminator
3. spray nozzles
4. trickle packing
5. heat source
6. float valve and fresh water inlet
7. overflow
8. bleed off
9. frost protection heating

Fig. 2: Sketch of a wet cooling tower [3]

The evaporated water is continuously replenished by make-up water. Due to the fact, that evaporation also increases the concentration of the dissolved solids in the cooling water, blow down of the cooling water is necessary.

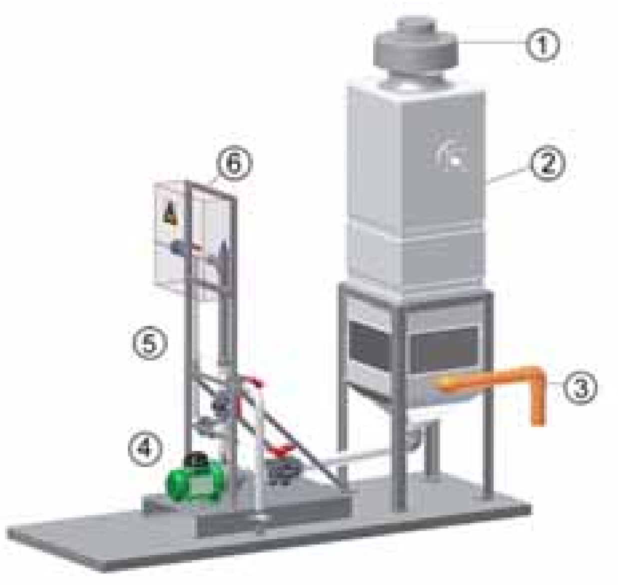
In wet cooling towers the wet-bulb temperature determines the degree of cooling and thus cooling below the ambient dry bulb temperature is possible. The characteristic approach temperature, which is the difference between the water outlet temperature and the ambient wet-bulb temperature, of wet cooling towers is from 4 to 8K.

Compared to dry coolers wet cooling towers are able to cool the cooling water to lower temperature level, requires less space and have much lower investment costs. The main disadvantages of wet cooling towers are hygienic problems, water consumption and high maintenance effort.

1.3 Improved wet cooling tower development

Due to the positive effects on the efficiency of a thermally-driven cooling system, the use of wet cooling towers is widespread. However, as this is an open system, the sanitation of the used water is essential. The necessary water-treatment-equipment is characterized by high-specific costs, both in terms of purchase as well as during operation, especially in the low power range.

In cooperation with partner companies a cooling tower system was developed, which has included an electrolytic water treatment. Water-treatment-equipment is not longer necessary which reduces both investment and operating costs. An integrated titanium anode avoids biocide infestation. Draining water (bleed off) due to high salt content is also no longer necessary under normal conditions, impacting very positively on the water consumption. In addition, the cooling tower due to its special design offers the possibility of an automatic discharge to avoid errors during wintertime and to reduce maintenance costs. The fan of the cooling tower is a low-power consuming ec-fan to reduce the electric consumption to a minimum (Fig.3).



1. low-power-consumption ec-fan
2. special packing for high surface
3. adjustable bleed off unit
4. cooling water pump
5. “ER”-water treatment unit
6. electric switchbox with control unit

Fig. 3: Sketch of the new developed cooling tower system with integrated water treatment

The cooling tower system has been developed for plant sizes from 7 up to several hundred kW cooling capacity. Especially in the smaller power range up to about 100 kW, the cost advantage is particularly relevant.

1.4 Practical experiences

Three pilot installations of this technology are realised in spring and summer 2010. The first installation at the office building of “Feistritzwerke-Steweag” in Gleisdorf, Austria is in operation since May 2010. The capacity and function of the cooling tower is very satisfying, the electrolytic water treatment is working well. Periodic measurements of the water quality are done to proof the efficiency of the action.

2. New system concepts for solar cooling systems

To meet the requirements of common buildings solar cooling plants are often designed to produce cold water. This water feeds cold distribution systems like fan-coils or cold ceilings. For new buildings together with the company Menerga new concepts have been developed to provide cooling systems with an optimized integration of solar energy.

In office buildings often more than 50% of the cooling capacity is used to feed the water-to-air heat-exchanger of the air-handling-unit. To be able to dehumidify the inlet air the cold water has to be on a temperature level of 6-7°C. Such low cold water temperatures lead to bad performances of the chillers.

The new Menerga-technology is based on an air-handling-unit with integrated sorptive dehumidification and adiabatic cooling. The unit is realising the cooling and dehumidification of the inlet air on a for thermally driven cooling systems extremely high level of efficiency and coverage. The chiller – thermally or electric driven – just needs to cover the remaining cooling load by feeding cold water to cold ceilings or activated components. The cold water temperature can be on a higher level which leads to a higher efficiency of the chillers and makes free-cooling easily possible. Such a solution has great economical advantages.

2.1 Function of the air-handling-unit with integrated sorptive dehumidification and adiabatic cooling

The warm and humid outside air is first passed through an absorber. In the absorber the outside air gets in contact with a highly concentrated lithium-chloride-solution (open sorption). The solution extracts the moisture of the outside air by absorbing it. In the next step the warm and dry outside air gets cooled down at the indirect adiabatic evaporative cooling unit by about 10K (Fig.4).

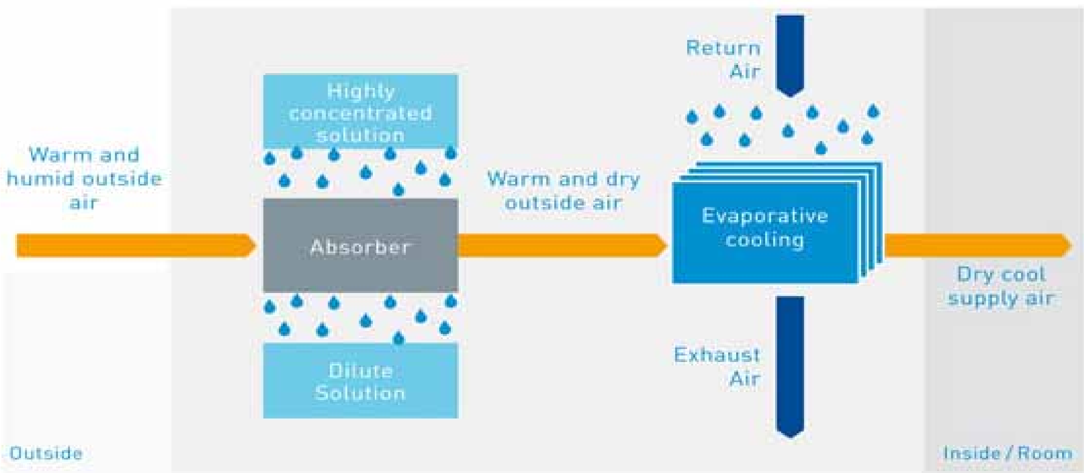


Fig. 4: Schema of the Menerga Sorbsolair

By absorbing the moisture the solution gets warm and is recooled at the integrated adiabatic cooling unit.

The regeneration of the solution is done in a regenerator, which has the same structure as the absorber. The solution must be heated up to only 55-70°C to give back the absorbed moisture to the outside air, which is sucked in addition to the ventilation air and expelled together with the exhaust air. The thermal energy to heat up the salt solution is provided by the solar system.

Because of the used solution storage tanks it is possible to operate the plant even if there is just no heat from the solar system available. In combination with the relatively low temperature level needed very high solar fractions of about 90% are possible. The solution storage tank is working as a latent storage because the heat necessary for the regeneration of the solution is indirectly stored in the form of regenerated salt solution.

The adiabatic cooling system consists of a double-recuperator, which is used for indirect cooling of the air by spraying water in the exhaust air channel. The cooling capacity is thereby significantly improved because the air is kept at wet bulb temperature all the way through the heat exchanger. The heat exchanger efficiency is on a very high level of 90% because it is always wet on the exhaust air side. This is possible through the use of plastic as material for the heat exchanger, which is completely corrosion proofed. Because the sorption process is cooled by the adiabatic cooling system therefore no external cooling equipment is required (Fig.5).

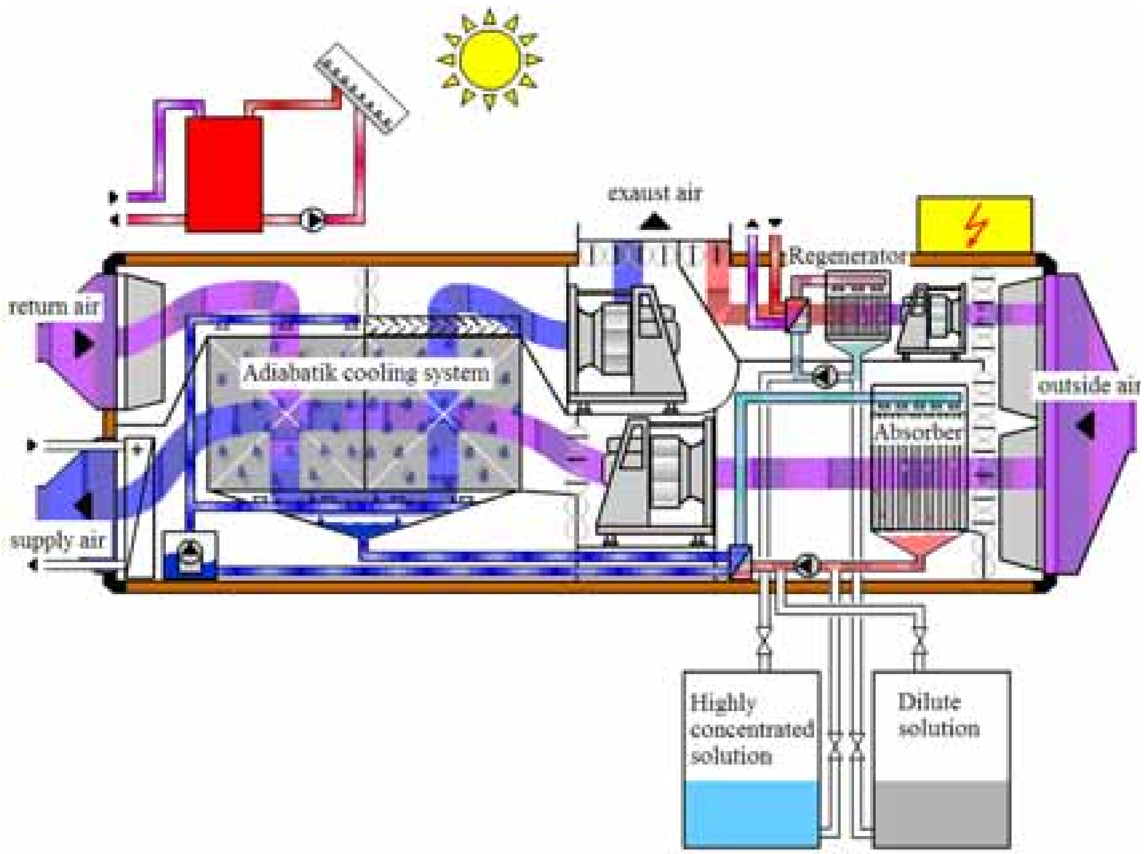


Fig. 5: Schematic drawing of a Menerga Sorbsolair unit

2.2 Advantages of the system

The advantages of the Menerga Sorbsolair over other systems for cooling and dehumidifying of air is particularly evident when the hx-diagrams of the different systems are compared (Fig.6).

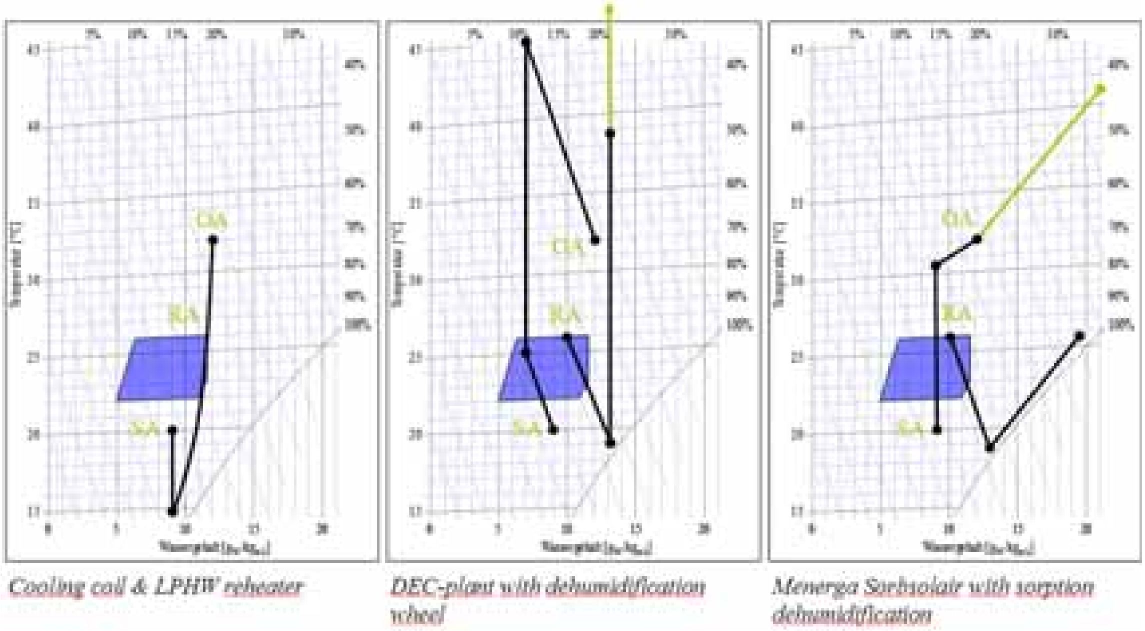


Fig. 6: Comparison of different cooling systems for ventilation units

Technical data of example unit „Menerga Sorbsolair Type 73 22 01" with 14.900m³/h:

Cooling capacity	103,9kW
Dehumidification capacity	65,7kg/h
Regeneration capacity	75,4kW

(Exhaust air 26°C / 45% rel. hum. and outside air 32°C / 40% rel. hum.)

The data shows a thermal COP of 1,4 with the possibility of using heat on a temperature level of 55-70°C for the regeneration. Because of the integrated solution tanks it's possible to run the device even if there is no solar heat available. These properties are leading to a solar coverage above 90% - even 100% was reached in already realised plants.

The electrical power demand for cooling is made up of the electricity consumption of the three circulation pumps and the fan for the regenerator. For the device with 103.9 kW cooling capacity described above an electric power of 3-5kW required.

Because of the high thermal efficiency relatively small solar collector areas are needed to drive the unit. For the device mentioned above about 150m² flat plate collectors are necessary. In combination with the not needed separate cooling tower this leads to lower investment costs.

The dehumidified supply air ensures a pleasant room climate with high comfort.

The dry air through the ventilation system adequately allows the easy use of chilled ceilings and activated components with no risk of falling below the dew point and condensation.

2.3 Realised plants

There are several Menerga Sorbsolair - plants realised all over central Europe.

- Toyota Salzburg
- Swimming hall Dahn (Frankfurt)
- Airport Munich
- inHaus 2 Duisburg
- Zentrum Future Emstek
- Kloben Verona
- TURRA S.R.L. Cazzago (I)
- University Hospital Freiburg
- HUC Coburg, SOBIC Freiburg
- and many more

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